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ESSAYS ON FINANCIAL SYSTEMS, BANKING CRISES AND EMERGING MARKETS

Submitted By

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To Shweta

Chapter 7: *Information-Induced Banking Failures in Emerging Market Economies (EMEs): An Analytical Afterthought*

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Declaration

*This thesis entitled: "**Essays on Financial Systems, Banking Crises and Emerging Markets**" has grown out of a series of papers written over my PhD years at the University of Warwick, U.K.*

I am submitting this PhD Thesis according to the rules and regulations regarding doctoral work submission at the University of Warwick, U.K. I certify that the papers produced in each section, are mine and are the result of my own research work. Where necessary, I have included proper referencing when making quotes from other work, published or otherwise.

A 'Library Declaration Form' and a Form regarding 'Submission of Doctoral Thesis at the University of Warwick' are attached. I certify that this Thesis has not been submitted for a degree at any other University.

Signed: Ashwin Moheeput (Revised version submitted in October 2009)

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Abstract (Non-Technical)

This thesis is divided into eight main chapters and makes contributions to the area of financial crises and international finance. The first chapter provides a general introduction to the thesis and highlights the main contributions of our work. The second chapter is a literature review which provides a well-defined structure to organise our thoughts about the literature on micro-systemic risks and Central Bank policy. The chapter initially reviews the literature for single-bank crises. It then proceeds on to provide a succinct account of multiple-bank crises and of financial crises that result from the interaction between banks and financial markets. The main value-added of this chapter is that it helps us identify those areas in the literature in which research work is missing. This provides legitimate foundation for building new models to address these issues. The subsequent chapters of this thesis have emerged to bridge these missing gaps identified in our literature review.

Chapters 3, 4 and **5** deal with banking panic transmission in two-bank scenario. With common investments affected by the same macroeconomic fundamental, a crisis that spreads from one bank to another has contagious and correlated elements. The purpose of these chapters is to provide a robust theoretical account that can enable us distinguish between these two elements in probability terms. We embed a two-bank model within a dynamic Bayesian setting and use the global games approach to derive the existence of trigger equilibrium in each bank. **Chapter 3** provides an overview of our banking environment. **Chapter 4** makes a contribution to derivation of the equilibrium concept and shows the equivalence between Perfect Bayesian Equilibrium (PBE) of our game and trigger equilibrium. **Chapter 5** encapsulates all results. We show the existence of contagion as one of `excess correlation' between banks. This allows us to depart from existing theoretical papers which explain contagion as interdependence. Furthermore, we show that whether contagion or correlation occurs is a function of the relative importance depositors attach to private vs public signals. The chapter ends by identifying some puzzles (zero-link, clustering and avoidance) which our paradigm can explain and throws light on ways (which are not captured by single-bank models) Central Banks should implement prudential policy measures.

Chapters 6, 7 and **8** deal with financial crises in open economies. An important limit of existing bank run models is that they are developed without taking into account the level of economic development of the economy in which they occur. We are interested in studying how financial crises occur in an Emerging Market Economy (EME) and, most importantly, how the nature of their occurrence differs when the exogenous macroeconomic constraints of an EME are duly accounted for. **Chapter 6** introduces the main banking environment we study in the subsequent two chapters. Important among the assumptions are that all depositors in the banking system are foreign investors (the economy is fully liberalised) and that banks have balance sheets characterised by liability dollarisation. We use the mechanism design approach to show the existence of a pecking order in allocation of resources and liquidity. In particular, we show that a banking allocation is weakly Pareto- inferior to that of a Planner who observes all structures of the economy but its stochastic fundamentals and who achieves second-best allocation. Once this banking allocation is derived, **Chapter 7** studies the nature of the transmission mechanism from a banking crisis to a currency crisis. We show that under certain parametric restrictions, Lender-of-Last Resort (LOLR) policies may be a conduit that generates a currency crisis. In a multi-bank setting, LOLR may even be sub-optimal since it may induce devaluation-based bank runs at other banks. **Chapter 8** studies the reverse causation from a currency crisis to a banking crisis. Both **chapters 7** and **8** offer useful guidance to policy. The success of a policy measure depends on its ability to restore the Planner's second-best. A number of policy options (e.g state-contingent controls) are studied and suggestions for design of exchange rate regimes, based on ability to ward off the twin crises, are offered as well.

Chapter 1

Introduction To Thesis

1.1 Comprehensive Overview of Our Approach and Contributions: What is New ?

The purpose of this thesis is to study the following two key questions in the areas of banking crises and international finance:

FIRST QUESTION – *How can we develop a model that can endogenously distinguish between banking contagion and correlation in probability terms, given that they co-exist in a given banking panic transmission with two banks that have correlated investments?*

SECOND QUESTION - *How can we embed a model of banking crisis within an Emerging Market Economy (EME) framework in a way that enables us to carry out a theoretical analysis of the transmission mechanism between a banking crisis and a currency crisis ?*

We arrive at these two questions after a comprehensive review of the relevant literature (**chapter 2**) which helps us identify key loopholes in the existing literature. The models we develop in the subsequent chapters of this thesis have been constructed to provide satisfactory answers to these two questions, so as to address these gaps in the existing literature. For the first question, our objective is to construct a theoretical model that:

[1] develops a new methodological approach to analysing contagion;

[2] offers a new interpretation for the concept of financial contagion;

[3] clearly distinguishes between contagion and correlation in equilibrium;

[4] explains contagion from micro-foundations of informational interplay;

[5] satisfies a number of stylized facts of empirical contagion;

[6] offers new insights on policy-making.

The paradigm we develop to answer the first question is enshrined in **chapters 3, 4** and **5**. The new banking environment is developed first in **chapter 3** by embedding a two-bank Diamond and Dybvig (1983) framework within a dynamic Bayesian setting. We allow the interplay between private signals of depositors and an endogenously determined public signal to explain crisis transmission across banks. The banking environment is designed so to allow for the application of the global games approach. An innovative element of our work is the development of a new methodological structure for our banking environment, which we do in **chapter 4**. Since the dynamic Bayesian setting requires the development of a Perfect Bayesian Equilibrium (PBE) and the global games methodology warrants the development of a trigger equilibrium, a key issue that we study is the link between the PBE concept and the trigger equilibrium. We are interested in showing whether a trigger equilibrium can be replicated as a PBE. This provides the cornerstone of our methodological structure for the first question. Building on this novelty, we study the main results of our findings for the first question in **chapter 5**. More details about the first question will follow at a later stage in this introduction. For the second question, our objective is to construct a model that:

[1] provides an interpretation of how the operation of the banking system will be affected by the exogenous macroeconomic constraints imposed by an EME;

[2] offers a welfare-theoretic interpretation of banking crises;

[3] provides a theoretical analysis of the circumstances under which a banking crisis will lead to a currency crisis;

[4] offers new insights on nature of policy interventions for banking crises in an EME;

[5] provides an analysis of the circumstances under which a currency crisis will lead to a banking crisis;

[6] contributes to the debate about choice of exchange rate regime based on fragility of financial systems.

While the aforementioned objectives for the second question are self-explaining, it is important to note that the main banking environment is developed in **chapter 6**. The key idea is to embed a one-bank Allen and Gale (1998) setup within a Chang and Velasco (2000a) environment and to use the mechanism design approach to study the optimality of resource (and liquidity) allocation for agents (Central Bank, commercial bank and forex market) in the financial system. Building on this innovative framework, **chapter 7** studies the link from a banking crisis to a currency crisis. The mechanism design methodology for addressing that particular link is developed and results discussed. In **chapter 8**, we use our banking environment to study the reverse causation link. The methodology for studying that link is developed and other results are also discussed in that chapter. More details about the second question will also follow at a later stage in this introduction.

At this stage, we are interested in providing the reader with an overview of our aims, objectives, approach, methodology and brief overview of our results. Please turn over for an illustration of Figure 1.1 which provides a skeletal outline of all chapters in this thesis, classified according to environment, methodology and results. In the material that follows Figure 1.1, we shall provide a comprehensive review of all chapters in this thesis by putting emphasis on the novelty of our work and by contrasting between our findings and those of the existing literature where necessary.

Figure 1.1 – Skeletal Outline of All Chapters

	CHAPTER TITLE	CHAPTER MISSION	
CHAPTER 1	General Introduction	Introduction To Entire Thesis	
CHAPTER 2	General Literature Review	Literature Review for Entire Thesis	
CHAPTER 3	Introduction to Financial Fragility and Informational Spillovers	Banking **Environment** for 1st Question	
CHAPTER 4	Financial Systems and Informational Spillovers: A Theoretical Characterisation	**Methodology** for 1st Question (Global Games and Perfect Bayesian Equilibrium (PBE))	**First Question**
CHAPTER 5	Modelling Banking Contagion as State-Contingent Change in Cross Bank Correlation	**Results** for 1st Question	
CHAPTER 6	Introduction to Financial Fragility in EMEs	Banking **Environment** for 2nd Question	
CHAPTER 7	Information-Induced Banking Failures in EMEs: An Analytical Afterthought	**Methodology** for 2nd Question (Mechanism Design) and 1st **Results**	**Second Question**
CHAPTER 8	Devaluation-Induced Banking Failures in EMEs: An Analytical Afterthought	**Methodology** for 2nd Question (Mechanism Design) and 2nd **Results**	
CONCLUSION	General Conclusion And Critical Appraisal	General Conclusion for Entire Thesis and Critical Appraisal	
BIBLIOGRAPHY	Bibliography	Reading Sources List	
APPENDIX	Non-Technical and Technical Appendix		

We now intend to provide a detailed overview of our exact contributions to the literature in each chapter and to provide a comprehensive discussion of how our approach (including environment, methodology and results) improves on that of existing models.

The occurrence of a major financial crisis every decade, makes the study of financial systems and of banking failures, a fascinating topic. Each financial turmoil episode that had plagued industrialised and emerging markets alike since 1970s, had confronted policymakers and academics with a new set of challenges. This thesis - the research work contained therein began in 2004 - was written with the East Asian crisis of the mid 1990s in mind. But at the time of writing up, a major financial disaster originating from the default of subprime mortgages in the US in 2007-2008, had begun to send shockwaves throughout the banking systems of the major financial centres of the world and had threatened to plunge the world economy into a depression similar to that witnessed in 1930s. In academic circles, the conventional macroeconomic paradigm was being challenged and new calls were being made for the development of a new framework, deeply rooted in microfoundations of financial markets and of financial intermediation, to offer better explanations for the occurrence of such events. The work contained in this thesis may help provide some useful contributions and illuminating guidance in that respect.

We have taxonomised our research thesis to reflect our broad interests in areas of banking and international finance, as diverse as financial contagion and fragility of banking systems in emerging markets. All papers are highly theoretical and most of the economic models developed therein, have been constructed to reflect some empirical facts in the literature. However, by keeping the structure of a model architecture within confines of established stylized facts, we hope that we have raised key issues that may help stimulate the thinking of academics who will have the wherewithal to take the material to the forefront of exciting new research. We also trust that our findings may help cast light on policy issues that may be pertinent to leading institutions such as Central Banks or the International Monetary Fund (IMF) and help practitioners better understand why events unfold the way they do. **Chapter 9** which will conclude the thesis, will summarise all contributions that we make to economic knowledge and a contrast will be made with the existing literature so as to provide clear guidance to the reader about the novelty of our work.

We begin our research work with a comprehensive literature review which provides a novel approach to organise the existing literature. This enables us perform a SWOT-type analysis[1] of the literature and to identify key unanswered questions in those areas in which research work is missing. As a result, the literature embodied in **chapter 2** provides a valuable springboard for developing subsequent chapters of this thesis. Our aim here is to identify a taxonomy that will enable us organise our thoughts about the literature on financial instability and banking crises. The theoretical and empirical literature on banking crises are rife with examples and illustrations of crises. While existing work in the literature takes different approaches, there is no well-defined way to organise our thinking about these approaches. Most single-bank papers focus on mutually-exclusive issues such coordination failure problems (Diamond and Dybvig (1983)), others focus on market failures, on informational asymmetries (Jacklin and Bhattacharya (1988), Allen and Gale (1998)) and on the contractual system of demand-deposit systems inherent in banking models (Jacklin (1987), Jacklin and Bhattacharya (1988), Peck and Shell (2003), Green and Lin (2003)). Others try to juxtapose coordination failure with informational problems (Goldstein and Pauzner (2005)). The literature for multi-bank models has been developed on a completely different pedestral since that literature focuses only on the nature of the transmission conduit linking banks. Eminent papers in that area include Allen and Gale (2000), Dasgupta (2004) and Chen (1999).

The analysis offered by **chapter 2** is innovative in that it endeavours to harness the rich literature on single-bank and multi-bank crises and to tax-

[1] SWOT - Strengths, Weaknesses, Opportunities, Threats.

onomise it according to some well-defined structure. We motivate the rationale for **chapter 2** by identifying a crisis from an anatomical perspective: a crisis has an initiator and a propagator. We begin with the literature on initiators by reviewing the single-bank scenario cases and focus on the various contributions that have been made in this area since the seminal work of Diamond and Dybvig (1983). The literature of the one-bank case can be bifurcated into *'inefficient' bank run* theories (contributions that highlight the existence of runs as emanating from coordination failure problems generated by 'sunspots') and *'efficient' bank run* models (models that highlight bank run problems as being generated from informational asymmetry problems about, say, the bank's fundamentals). What triggers a banking crisis is unpredictable in the former case (bank runs are a cause of banking failures) but may be predictable in the latter case (bank runs are a result of imminent banking failures) depending on how the informational process is generated. Shin (2009) argues that the most recent banking crisis to have hit the UK economy, the Northern Rock crisis of 2007-2008, is of the latter type. We move on to analyse the propagation side of our proposed structure. Here, we are essentially concerned with the literature of banking crises and systemic risks. We propose two ways of organising our thoughts about systemic risks.

The first approach is to survey the literature of contributions that highlight multiple bank runs but no financial markets. Here, we identify several sources of connections across banks:

[1] (*Network models of financial contagion*) Banks may engage in direct balance sheet connections in that they may cross-insure deposits as insurance against negatively correlated liquidity shocks (Allen and Gale (2000), Dasguta (2004)) or may engage in interbank lending (Rochet and Tirole (1996)) - meaning that banks hold interbank claims on each other. These models rely on simple networks[2] of banks that have symmetric or asymmetric exposure to each other's

[2] The choice of network structure is exogenous in these models.

claims. In a more recent contribution, Gai and Kapadia (2008) try to provide an understanding as to how financial intermediaries connect as networks by applying statistical techniques from network theory, to arrive at a more general model of contagion with complex financial systems. Since balance sheet connectivity may be further complicated by interractions between financial intermediaries and financial markets and by the development of new financial products such as Collateralised Debt Obligations (CDOs) or Credit Default Swaps (CDSs), Gai and Kapadia (2008) try to study the relationship between financial connectivity and contagion, by providing a network structure that can isolate idiosyncratic shocks from aggregate shocks in a given systemic risk.

[2] (*Informational channel of financial contagion*) The informational channel provides another conduit that connects banks. A crisis in one bank may cause a confidence crisis among depositors of other banks and cause them to reassess their beliefs of their bank's fundamentals. As a result, a crisis erupts with systemic proportions (Chen (1999), Archarya and Yorulmazer (2008)).

[3] (*Commonality of investors or in holders of claims and obligations*) Here, banks may have common investors. A crisis in one bank prompts investors to reassess their portfolio and affect their risk-taking appetite. This may mean investors withdrawing from other banks (Vaugirard (2004), (2005)).

[4] (*Commonality in investment or homogeneity in the structure of balance sheets*) This channel of connectivity across banks originates from the asset side. Balance sheet commonality may also be classified under this channel. Cifuentes, Ferrucci and Shin (2005) argue that the effect of default in banks, may trigger a series of defaults in other banks that are forced to write down the value of their assets. A decline in the value of these assets may affect the balance sheet of otherwise healthy banks as well. As a result, contagion on the claims or obligation side of their balance sheet (due to depositors running on their banks) is reinforced by contagion from the asset side. An illustration of this phenomenon comes from industrialised economies in which banks have common exposure to real estate. A collapse in house prices generally affects banks that have commonly invested in the housing sector. The financial crisis of 2007-2008 in the developed countries can be used as an example to showcase the importance of this channel, although the presence of other complex factors in the recent turmoil, dwarf this channel as possible explanation. In the developing world, an example of homogeneity in the balance sheet structure comes from the fact that banks may engage in liability dollarization i.e they have a balance sheet structure with assets denominated in home currency and liabilities denominated in dollars. A currency devaluation here affects all banks in a similar way.

The second approach to modelling systemic risks is to consider the interaction between banks and financial markets. A notable tendency in the literature is to consider banking systems with homogenous banks or with heterogenous banks. *'Homogenous' banks* may use financial markets to trade their illiquid assets, to issue claims against the illiquid asset (securitization) and to act as a contingency providing insurance against aggregate risks that they face. We identify the main sources of market failure that may prevent full provision of liquidity by financial markets to banks e.g incomplete information setup and market structure factors like abuse of dominance and monopoly. *'Heterogenous' banks* may use the interbank market for the same purposes as highlighted for financial markets. However, the sources of market failure in the interbank market differ. The literature on interbank markets as a mechanism of providing liquidity to banks suggests that the interbank market fails with the presence of positively correlated shocks across banks. Similarly, Goodhart and Huang (2005) and Rochet and Vives (2004) argue that it cannot be relied upon as a source of liquidity provision if there are coordination failure problems and free riding in liquidity provision. An important result in the existing literature, is to identify the conditions under which (financial) market failures may lead to inefficient liquidity allocation to banks and to explore the circumstances in which this may be welfare reducing. Using conditions akin to the First and Second Theorems of Welfare Economics, Allen and Gale (2004) show that, while demand deposit contracts offered by banks are incomplete contracts (and thus non-contingent), the interaction between banks and financial markets leads to inefficient allocation of resources and liquidity if the financial market is incomplete. In the presence of a complete financial market but incomplete demand deposit contracts, the allocation becomes only constrained efficient. The contribution by Allen and Gale (2004) is important since it provides a welfare theoretic measure that can be used to assess the welfare properties of any prescribed policy measure.

In a nutshell, apart from providing a comprehensive review of the literature, the main contribution of **chapter 2** is to form a taxonomy that enables us to situate the contribution of relevant papers in the literature within a well-defined context. The useful benefit of having a well-defined taxonomy is that it provides a SWOT-type analysis of the context within which existing work has been done. This puts us in a pole position to identify those key areas in which theoretical work is missing and which could potentially be areas for future research work. All subsequent chapters that embody the essence of the main contributions of this thesis to economic knowledge, have, in fact, been written to provide answers to some of the missing areas we identified in **chapter 2**. In the main parts of the thesis, we provide a detailed account of the questions we are trying to answer, the main scientific approaches adopted as economic methodology and a thorough discussion of our innovative results. Where necessary, we provide a contrast between our contributions and those of the existing literature by highlighting on some of the weaknesses of existing models and by documenting how our paradigm succeeds in addressing these frailties. It must be stressed out that, while all subsequent chapters after **chapter 2** deal with bank run models, the nature of the bank run is different. **Chapters 3, 4** and **5** deal with Diamond and Dybvig (1983) type of banks. The nature of coordination failure and multiple equilibria are highlighted in each bank but we embed the global games approach of Morris and Shin (1998) in this banking environment in order to get rid of equilibria multiplicity. The three chapters following **chapter 5** deal with bank runs of the Allen and Gale (1998) type and are not plagued by coordination failure problems. They contain an information device that coordinates the decisions of depositors and that makes any decision (i.e either to stay or withdraw) a dominant strategy.

In **Chapters 3, 4** and **5** , the complex issues of multiple banks, informational spillovers and financial contagion and correlation, are addressed. In an economic environment in which banks are preceived to be commonly connected to some risky technology, a given banking panic transmission has contagious and correlated elements. Both concepts are inextricably linked and the literature lacks a theoretical model that can help distinguish between them. In **chapters 3, 4** and **5**, we are interested in building a microfounded model that enables us distinguish between these two elements in probability terms. We proceed by adapting a dynamic Bayesian setting to a two-bank environment, with banks having risky investments that are perceived to be connected to some common macroeconomic fundamental. Depositors of either bank are assumed to observe their bank's idiosyncratic fundamental through some noisy signal technology but those who move at a later stage, have the added advantage of observing the event in the first bank. They may thus strategically use the event in the first bank to make stochastic inferences about the state of the common macroeconomic fundamental. The informational spillover that results from this strategic inference, provides the conduit that transmits a crisis from one bank to the other and that fundamentally alters the dynamics of the outcome of the game.

Chapter 3 introduces the main theoretical paradigm and develops the environment in which banks operate. We have two Diamond and Dybvig (1983) banks and no financial markets. The banks have common investment in a risky portfolio and the risky portfolio is affected by some macroeconomic fundamental. Banks are modelled essentially as deposit-taking institutions and the concept of a banking crisis is analysed mainly from the point of depositors withdrawing their deposits from their banks prematurely. The novelty of **chapter 3**, compared to existing work in the literature, is to juxtapose the Diamond and Dybvig (1983) framework with the global games methodology, as a way of eliminating coordination failure problems. Morris and Shin (2000) study the global games approach within a one-bank context but their contribution was merely meant to analyse the circumstances under which multiple equilibria or a unique equilibrium will result.

Our approach differs from Morris and Shin (2000) in several ways. Unlike Morris and Shin (2000) who focus on partial strategic complementarities in payoff structure, we introduce global supermodularities or strategic complementarities in depositors' payoff structure. Since we intend to study the global games approach as a means to an end rather than as an end in itself, this enables us to rationalise the global games approach in a context with more intricate payoff structure (such as ours), without being bogged down by the extra theoretical considerations developed by Athey (2000)[3]. At the same time, we allow depositors to receive a noisy information of their bank's risky fundamental and to have some prior belief of the state of the common macroeconomic fundamental. For the banks' investment portfolio, we also develop the 'dominance region' as a function of risky investment parameters - which is vital for the global games approach to work in our setup. While the development of the concept of 'dominance region' is common in global games analysis, a novel element in our work is to distinguish between 'weak' and 'strict' dominance regions. The former depicts a case where a dominant strategy exists in depositors' actions, depending on the realisation of the state of the common macroeconomic fundamental. The latter describes a case where this dominance arises, irrespective of the state

[3] Athey (2000) identified two conditions that must be satisfied for the global games approach to work in the absence of global supermodularities in the payoff structure: [1] Single-Crossing Property in payoff structure and [2] Monotone Likelihood Ratio Property in the noisy element of the signal.

of the common fundamental. The distinction is important when we show the existence of a trigger equilibrium. Furthermore, in Morris and Shin (2000), the noisy information concerns the deposit payoffs whereas in our case, it concerns realisations of the risky investment.

The most important difference between our method and that of other global games models that study banking, is that we introduce a sequential structure in depositors' withdrawing decisions and we allow for strategic interactions between depositors of different banks. We assume that, in the interim period, depositors of one bank first take their decision as to whether to stay or withdraw. The event in that bank becomes public knowledge (the bank either fails or succeeds). Then, depositors of the other bank move to take their decision. Depositors of the second bank thus observe the public information regarding the event about the first bank as well as their own private information about their own bank. They may thus strategically use the public signal about the event in the first bank to complement their private signals. In Morris and Shin (2000), there is one bank only. Thus, strategic interractions between depositors of different banks are absent. Dasgupta (2004) also studies two banks but there are no strategic interractions between depositors of the two banks. Thus, the development of the equilibrium concept in Dasgupta (2004) is undertaken, assuming only one bank. Chen (1999) studies multiple banks but does not use the global games approach.

Our banking environment is rich and departs radically from other papers in the literature. The common exposure of banks to the macroeconomic fundamental is new and creates strategic inferences for depositors of the second-mover bank. The sequential approach that we adopt, puts us in a strong position to analyse the dynamics between private information flows and public information flows, as a way of triggering banking crisis transmission. In **chapter 4**, we aim to characterise the equilibrium properties of depositors' withdrawing game, given the banking environment we develop in **chapter 3**.

The main contribution of **chapter 4** is to rationalise the adoption of the global games methodology to our set-up and to show the existing of trigger equilibria in depositors' strategies. Doing so, enables us to eliminate several uncertainties in subsequent analysis. One of the key problems in the existing literature, with multiple equilibria embedded in bank run models, is that the outcome of the game is unpredictable. An important problem with equilibria multiplicity in a model with several banks, is that it becomes very difficult to pin down the exact cause-effect relationship. If the outcome at one bank is uncertain, how can we realistically make predictions about how a banking crisis will spread from one bank to another? Thus, the main motivation and innovation of **chapter 4**, consist of finding a solution to that conundrum. The global games approach that we use for that sake, has its advantages. In addition to removing multiple equilibria (and thus unpredictability), it endogenises the probability of a given outcome. This feature will prove crucial when we discuss the merits and innovations of **chapter 5**.

While the global games methodology has been used in several areas of applied finance and has embraced static games of incomplete information (Morris and Shin (1998), (2000), Dasgupta (2004)[4], Vaugirard (2004), (2005)), adopting the approach to a dynamic setting with strategic interractions between cohorts of agents moving at different points of time, is somewhat trickier. The theoretical literature in the area of dynamic global games is still at embryonic stage and has, so far, only studied the circumstances under which multiple equilibria will result (as opposed to unique equilibrium), by incorporating learning mechanisms within sequential move games with incomplete information. Notable contributions to this literature come from Angeletos, Hellwig and Pavan (2006), (2007). Rather than studying the nature of equilibrium with a stylized approach, the theoretical contribution embodied in **chapter 4**, studies a different question

[4]Again, Dasgupta (2004) studies two banks but there is no strategic interraction between depositors of these two banks. Hence, the equilibrium concept is derived, as if there is only one bank.

which has, hitherto, not been addressed in the literature of banking and of dynamic global games: the connection between the Perfect Bayesian Equilibrium (PBE) concept and global games approach. The innovative contribution of this chapter is manifold: we use the global games approach to pin down the existence of a trigger equilibrium in each bank's idiosyncratic fundamental space. Most importantly, we are able to establish a connection between the Perfect Bayesian Equilibrium (PBE) concept - which provides the solution concept for a dynamic Bayesian setup - and the trigger equilibrium. This result allows us focus on trigger equilibrium throughout and has the added advantage of enabling us endogenise the probability of events in each bank.

We start **chapter 4** by characterising the equilibrium strategy of each depositor in terms of trigger strategies. This chapter provides the main methodological treatment for solving the equilibrium in the paradigm we consider for the first question. For depositors of the first bank, their information set is their private information about their own bank's fundamentals and a prior belief about the common macroeconomic fundamental. For those of the second mover bank, their information set is their private information and a posterior belief about the state of the common macroeconomic fundamental. The posterior belief is created essentially by Bayesian mechanics. We then move on to analyse the equilibrium properties of the game. Due to its sequential nature and incomplete information, we characterise the PBE of the game. As aforementioned, our approach is complicated in that we have a cohort of depositors taking their decisions simultaneously. In this respect, a legitimate contribution of **chapter 4** (which is completely new to the existing literature) is that it shows that the PBE of depositors' game across the two banks, can be represented as a trigger equilibrium in each bank. Our approach differs from Angeletos, Hellwig and Pavan (2006), (2007), in that they focus on deriving the conditions for multiplicity of equilibria in a dynamic game setting with the private and public information being on the same random evolutionary variable. By contrast, in our work, the private signals are on different variables (idiosyncratic fundamentals of each bank for each group of depositors) and the public signal is on an endogenous event rather than on some fundamental. Our approach has an appealing feature in that it enables us to parcel out the performance space of each bank and to characterise in probability terms, the event taking place in each bank.

Building on this exciting and innovating result, **chapter 5** takes the reader to appreciate the qualities and contributions of our paradigm on different fronts. The intuition behind banking panic transmission becomes clear. When a bank has failed and the event becomes public news, depositors of the other bank will strategically use that event to infer about the state of the common macroeconomic fundamental. That inference is what creates informational spillovers in our model. While these depositors will base their decisions on their private information as well, they observe the public event in the first bank (say, a bank failure), make strategic inferences about the state of the common fundamental (from Bayesian mechanics, their posterior estimate is that the common macroeconomic fundamental is more likely to be in its bad state) − and the interplay between their private information and the public information will bias their decision towards staying or withdrawing. If they stay, it means that their private information was strong enough to offset the impact of the public news of the first bank's failure on their inference. If they withdraw, there are two possibilities: either their private signal was low as well and was thus complemented by the public news of the failure of the first bank; or their private signal was strong but was more than offset by the impact of the public news. This interaction between private signals and public information, as a way of transmitting a crisis across banks, is a fundamental novelty of our approach - and has, hitherto, not been discussed in any dynamic models of banking contagion. Hellwig (2002) derives the parametric restrictions that lead to uniqueness as opposed to multiple equilibria in a static game of incomplete information, as a function of the interplay between private and public signals. Our result may thus be viewed as a dynamic adaptation of the Hellwig (2002) approach, to a multi-bank world. Thanks to the global games methodology, we get the new insightful result of being able to distinguish between financial contagion and financial correlation as equilibrium phenomena and to make each of these two events, a distinct result of the interplay between private signals and public signals.

We are in a position to bifurcate a given banking panic transmission event into two events which are inseparable from each other: financial contagion and financial correlation. We present contagion as an event in which the failure of one bank causes the failure of the other, when no such failure would have occured to the other bank otherwise. In the performance space highlighting the event in each bank, we are capable of distinguishing between contagion and correlation in probability terms and of showing contagion as an event in which the second bank fails (or succeeds) if and only if the first bank fails (or succeeds). In so-doing, we arrive at three sub-conclusions about our results, which constitute the essence of the contributions we make to the literature:

[1] In the event space of each bank, we come with the conceptually innovative result of being able to distinguish between contagion and correlation, by showing contagion as a case of excessive correlation in some states of the world. This idea departs radically from the existing literature which explains contagion from the narrower perspective of *'interdependence'*. If financial contagion exists, then it is essentially represented as a case of *'excess correlation'* between banks. Our work constitutes the first theoretical attempt to model banking contagion as *'excess correlation'* . The main papers in the existing literature (e.g Allen and Gale (2000), Dasgupta (2004), Chen (1999)) describe contagion mainly from the vantage point of 'interdependence'. In an empirical work on contagion in financial markets, Pesaran and Pick (2007) explain why constructing models of financial contagion based on this narrow version of interdependence, may not lead to empirically plausible results. In the main text, we highlight why such an approach is implausible and why, in our opinion, our concept of contagion as a state-dependent case of 'excess correlation' is more robust. Our contribution may thus be viewed as a theoretical vindication of the empirical results of Pesaran and Pick (2007);

[2] A theoretically appealing feature of our setup is that we are capable of explaining contagion vs correlation as a function of the relative importance depositors attach to private vs public information. For instance, we show that contagion is always characterised by public informational dominance in depositors' information set. In a given banking panic transmission across banks, which outcome is going to prevail is dependent on the relative importance of private information to public information for depositors of the second bank. We show that, if the public information is relatively more important in depositors' information set, a given banking panic transmission is characterised as contagion. We pioneer the concept of *Public Informational Dominance* to explain this. Although similar in insight to the herding result of Banerjee (1992), contagion is not herding in our model because there is no loss of information aggregation in our setup and depositors do not ignore their private information at any point. In the performance space, we distinguish between contagion and correlation in probability terms. Any event in which banking panic transmission is avoided, is one characterised by *Private Informational Dominance* i.e depositors of the second bank give relatively more importance to their private signals than to the public news and the private signals about their bank's fundamentals, are strong.

[3] Our results are new in that we can distinguish between positive and negative contagion and between positive and negative correlation. We can show that, with the same mechanism used for Bayesian inference, contagion cannot just be viewed as a case of bank failures but may also be viewed from the vantage point of bank successes. The analysis for successes across banks is based on the same mechanics as for bank failures.

Chapter 5 ends by showing the contribution of our paradigm to the world of policy-making. On the empirical side, our setup is appealing in that we are able of simultaneously explaining three important puzzles (zero-link, clustering, avoidance puzzles) in the literature of banking contagion. We first document the empirical validity of our model construction by showing that our setup satisfactorily explains all these puzzles in the literature of financial contagion (

that existing bank run models cannot explain). We show that our approach can explain why banking crises may spread among banks that are completely unrelated (*zero-link puzzle*), why they may cluster among identical banks only (*clustering puzzle*) and why some identical banks may avoid the crisis transmission whereas others cannot (*avoidance puzzle*). The ability to resolve key puzzles is not only an important contribution to the literature, but also, an indicator that our model construction framework and structure, are robust.

By distinguishing between contagion and correlation in probability terms, we are capable of defining the dividing line between microprudential and macroprudential banking regulation. If a given banking panic transmission in an economy, is characterised as correlation rather than contagion, our model advocates the use of macroprudential regulation as policy measure. In the reverse case, our model would advocate the use of existing microprudential measures but, given the informational spillover channel embedded in our framework, we rationalise the case of confidence safeguards to be adopted throughout the entire banking system of a country. An innovative feature of our paradigm - that makes it stand out of the crowd on the policy front - is that we can capture strategic interractions between different banks by allowing for sequential moves for cohorts of depositor groups. This gives us the advantage of introducing the concept of *'policy externalities'* i.e a microprudential policy measure administered at a crisis-catalyst bank may have positive or negative spillover effects on behaviour of depositors in other banks. We rationalise the adoption of generalised confidence safeguards throughout the rest of the economy, as potential insurance mechanism to contain these externalities.

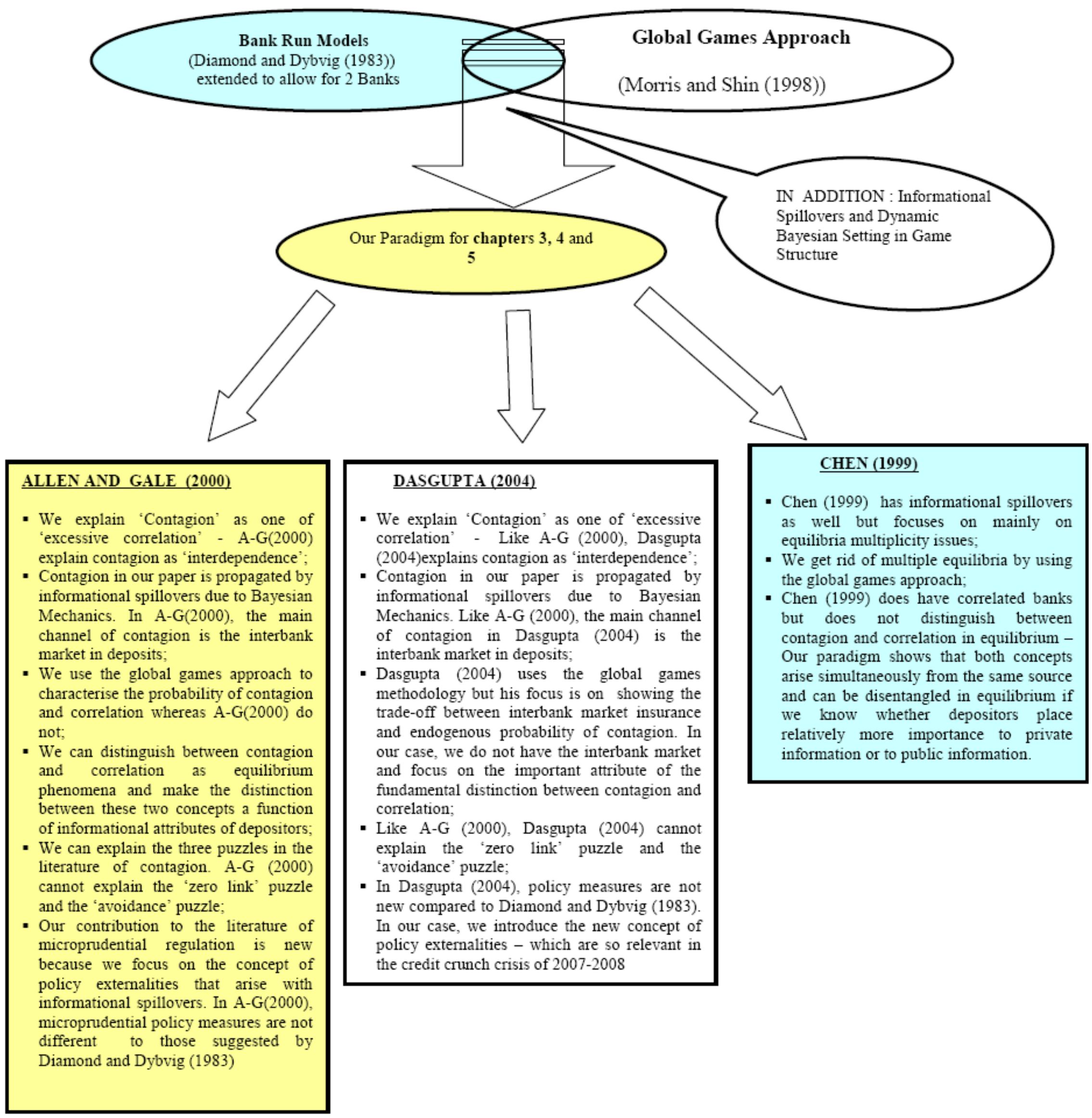
What exactly justifies the adoption of such generalised safeguard measures ? We pioneer the concept of *'intertemporal banking crisis substitution'* which may occur when a policy action implemented at a crisis-catalyst bank is wrongly interpreted by depositors of other banks, and leads to a crisis at these other banks. This idea is new and offers fresh insights on how Central Banks must intervene to administer policy at a crisis-catalyst bank - in ways that are not captured by single-bank models. In the existing literature which focuses on contagion from the narrower perspective of interdependence, microprudential measures at the crisis-catalyst bank are enough to ward off a crisis transmission across banks, in that they help to preserve the balance sheet of the crisis-catalyst bank. Thus, the conduit that links one bank to the other, prevents a crisis from being transmitted contagiously throughout the system. In our model, due to informational channel, a policy administered at one bank may create informational externalities of its own on the rest of the economy. Depositors in other banks, may give different interpretations to policy measures administered at one bank. As such, it becomes imperative to accompany microprudential measures by generalised confidence safeguards as an economy-wide insurance mechanism to prevent intertemporal substitution of banking crisis.

Although written with the East Asian turmoil in mind, we endeavour, where possible, to relate the contributions of our research work to the contemporary financial crisis of 2007-2008. The Northern Rock crisis in the UK in 2007 is used as example in **chapter 5** to illustrate how our framework (embodied in **chapters 3, 4** and **5**) can be used to rationalise the occurrence of certain events that had occurred in the current financial turmoil. Shin (2009) explains how the Northern Rock banking crisis of 2007-2008 in the UK offers a different perspective on the nature of bank runs, compared to that offered by banking crisis models such as Diamond and Dybvig (1983). The case of the Northern Rock crisis of 2007 in the UK illustrates well the point that depositors in an economy are sensitive to particular measures adopted by a Central Bank in favour of any bank experiencing financial trouble. We complete **chapter 5** by providing a reconciliation of Shin's (2009) views on the Northern Rock crisis with the main findings of our work. [Please refer to next couple of pages (Figures 1.2 and 1.3) for a pictorial representation of a contrast between our work and the existing literature and for a summary of the main contributions embodied in **chapters 3, 4** and **5**].

FIGURE 1.2: Key Questions and Answers (Chapters 3, 4 and 5)

FIRST QUESTION – How to develop a model that can endogenously distinguish between Banking Contagion and Correlation in probability terms and that:	**Our Approach and Methodology**
▪ offers a new banking environment approach to modelling financial contagion	=> Embed a 2-bank Diamond-Dybvig (1983) setup within a dynamic Bayesian structure with private and public signal (**Chapter 3**)
▪ develops a new methodological structure to modelling banking contagion	=> Use of global games methodology and show the equivalence between Perfect Bayesian Equilibrium (PBE) and trigger equilibrium (**Chapter 4**)
▪ offers a new interpretation for the concept of financial contagion	=> Endogenous explanation of contagion as *'excess correlation'* rather than as *'independence'* (**Chapter 5**)
▪ explains contagion from micro-foundations of informational interplay of agents	=> Explanation of contagion when there is *'Public Informational Dominance'*. Contagion is always avoided when there is *'Private Informational Dominance'* (**Chapter 5**)
▪ satisfies a number of stylized facts of empirical contagion	=> Explanation of: **[1]** *Zero-Link Puzzle* **[2]** *Clustering Puzzle* (**Chapter 5**) **[3]** *Avoidance Puzzle*
▪ Offers new insights on policy making	=> Provision of a new framework for distinguishing between microprudential measures and macroprudential measures and introduction of the concept of *'Intertemporal Substitution of Banking Crisis'* when standard policies are applied to crisis-catalyst banks (**Chapter 5**)

FIGURE 1.3: Illustration of Chapters 3, 4 and 5 - Similarities and Differences with the Literature – What is our Contribution to Knowledge?



In the chapters following **chapter 5**, we are interested in a rather different question. Banking models in the literature have been developed without taking into account the macroeconomic environment in which these banks are operating. For instance, macroeconomic constraints that are adopted for some exogenous reason, may ostensibly impinge on the ability of the banking system to fulfill its liquidity insurance role effectively. The presence of these constraints may affect the occurrence of banking crises in a way that is fundamentally different to what is normally proposed by current models that ignore these constraints. This augurs a different approach to policymaking for these economies, compared to what is currently being suggested. In **chapters 6, 7** and **8**, we study an open-economy version of a banking system with a number of Emerging Market Economy (EME) macroeconomic constraints and, in particular, we intend to focus on the relationship between a banking crisis and a currency crisis. Important among the assumptions are that all depositors in the banking system are assumed to be foreigners who are endowed with dollars (i.e foreign currency) and that banks have balance sheets characterised by liability dollarisation (i.e have assets denominated in home currency and liabilities denominated in dollars).

Chapters 6, 7 and **8** study a fundamental question of a completely different nature. In these chapters, we deal with bank run models of the Allen and Gale (1998) type. One of the interesting facts about these bank run models is that they are developed without taking into account the specificity of the economic system in which the banks operate. In general, bank run models such as Diamond and Dybvig (1983), Jacklin and Bhattacharya (1988), Allen and Gale (1998), (2004), were developed to answer theoretical issues in liquidity insurance provision and the optimal form of financial contractual systems and risk sharing. They do not make allusion to possible exogenous constraints that may be imposed on the operation of the banking system, by macroeconomic features of the economy. A banking crisis in a developing country has features that are different to those occurring in a developed country. An emerging market framework, for instance, imposes certain macroeconomic features that we highlight in **chapter 6**, as stylized facts of an emerging market economy. In particular, we document that emerging market economies have financial systems that are often characterised by soft pegs, short-term capital inflows intermediated through the banking system as deposits, banks characterised by liability dollarisation in their balance sheets and deposit insurance systems acting as implicit guarantees of depositors' investments. These exogenous macroeconomic features make traditional banking models obsolete in terms of answering key issues that may arise from financial crises present in emerging economies.

As a result, in **Chapter 6**, we develop an environmental framework that is new to the literature and that embeds an open economy version of the banking system of Allen and Gale (1998), into a framework that takes into account the list of macroeconomic features of an emerging market. Our aim, in the two chapters that follow, is to examine what challenges these exogenous constraints will present to the operation of the banking system and to study the circumstances under which a financial crisis will inexorably flow from one sector (say, banking system) to another (say, foreign exchange market) and vice versa. Our approach to modelling the economic environment is similar to Chang and Velasco (2000a), in that the financial system acts as a collective mechanism designed to implement allocation of resources. The financial system consists of a Central Bank, commercial banks of the Allen and Gale (1998) type and a foreign exchange market. Our modelling structure of the environment, however, differs from Chang and Velasco (2000a) in that we do not deal with multiplicity of equilibria and about whether particular exchange rate regimes help contain the 'twin crises' phenomenon. Rather, as the subsequent chapters suggest, we are interested in the issue of causation of financial crises from a banking sector to foreign exchange sector and vice versa in an emerging market version of a banking system faced with a number of exogenous macroeconomic constraints.

This idea of developing a theoretical model that addresses the issue of causation, is new and bridges the gap that exists in the existing literature, which, albeit extensive, has focused essentially on the empirical side of panic transmission in open economies. **Chapter 6** develops an analytical structure in which all depositors are assumed to be foreign investors. They have an endowment of one dollar each and they invest their dollar in their banks as deposits. The banks are responsible for honouring their debt obligations to depositors in dollars, whenever payment is due. However, we assume that banks invest in assets denominated in a local currency (denoted as pesos), say, housing sector. The exchange rate regime is initially assumed to be a credible soft peg. This characterisation leads to an extra feature for banks' balance sheets: in addition to the standard asset-liability maturity mismatch, banks have balance sheets plagued by asset-liability currency mismatch or liability dollarisation.

Chapter 7 takes the theoretical paradigm developed in **chapter 6** to examine the nature of the transmission process from a banking crisis to a currency crisis. As aforementioned, the Central Bank, commercial banks and the foreign exchange market participants act a collective mechanism designed to implement Pareto optimal allocation of resources and optimal provision of liquidity to consumers. The first part of the chapter studies the circumstances under which efficient provision of liquidity and allocation of resources, are provided by different types of mechanisms. A new contribution to the literature on EME financial system allocation. is that, using the mechanism design approach, there is a general pecking order in the implementation of resource allocation. In particular, we show that a banking allocation results in a weakly Pareto-inferior allocation to that of a Planner who is assumed to control all flows of resources across time and states but who cannot observe the stochastic fundamentals of the economy. When bank runs occur with positive probability, the allocation is strictly inferior. When they are prevented, the resulting allocation replicates that of the Planner in achieving the Second-Best provision of liquidity. In this state, the banking allocation can only insure depositors against the liquidity needs but not against aggregate risks in the economy due to the presence of stochastic fundamentals. As a result, the banking allocation results in a state-contingent term structure of payments to depositors.

The first mechanism we study, is that of the Central Bank as a social Planner who can observe the true realisation of the risky fundamental. Using the Revelation Principle, we show that by having complete information about the structure of the economy across time and across different states, the Central Bank offers a direct incentive-compatible mechanism that achieves a First-Best solution. The term structure of payment to depositors results in a non-contingent allocation for depositors. In this First-Best scenario, the Central Bank offers a risk-sharing incentive compatible mechanism that offers fully insurance against all liquidity and aggregate risks in the economy. Banking crises and currency crises (henceforth dubbed, the 'twin crises') are also prevented. The second mechanism we study is that of the Central Bank as social Planner but here we introduce the more realistic assumption that the Central Bank is unable to observe the realisations of the risky fundamental of the banking system.We show that this mechanism can only achieve the Second-Best allocation of resources in that the Central Bank can offer a mechanism that is only approximately incentive compatible and that can only approximately achieve risk sharing allocation. The Central Bank can be shown to be able to hedge against liquidity risks in the financial system only but not against aggregate risks. This leads to a state-contingent demand deposit payment to depositors. In the second-best scenario, the twin crises are pre-empted as well.

We then move away from the idealist world of Central Bank as Planner and study the allocation of resources and liquidity under a commercial banking system offering demand deposit contract. Since we are not interested in equilibria multiplicity, we get rid of the problem by assuming that depositors receive a perfect signal of their banks' idiosyncratic risky fundamentals. As in Allen and Gale (1998), we are able to pin down the existence of an equilibrium threshold in the bank's risky fundamental above which it is dominant for depositors to stay and below which it is dominant to withdraw. We show that banking crisis may occur with positive probability, depending on the realisation of the bank's risky fundamental. When no banking crisis occurs, the banking system replicates the allocation of the planner under the Second-Best outcome. In instances in which a banking crisis occurs, the outcome is strictly Pareto inferior to that of the planner under the Second-Best solution. Thus, from a mechanism design perspective, our contribution shows that when the probability of banking crisis is duly accounted for, a banking system allocation is weakly Pareto inferior to that of the Planner when the risky technology of the banking system has stochastic returns that are not observed by agents and authorities alike.

An interesting aspect of this result is to study the consequences of banking crises (when they occur with positive probability) and the potential spillover effects to other sectors of the economy. This is the treatise of the second part of **chapter 7**. Using a welfare theoretic approach to modelling banking crises in EMEs, has the appealing feature that it enables us to study the welfare implications of potential policy measures designed to solve a banking crisis, as a way of restoring the Planner's Second-Best allocation of resources and liquidity. We begin with the assumption that the exchange rate regime is a soft peg. A bank run, in these circumstances, will occur if depositors receive bad news of their banks' assets (i.e information-driven).

In addition to modelling welfare properties of a banking allocation as opposed to that of a Planner through the mechanism design approach, important contributions to the literature that we make, come from a detailed analysis of the circumstances under which a crisis will contagiously flow from one sector (say, banking) to another (say, foreign exchange). An important part of our work concerns the application of Lender-of-Last-Resort (LOLR) in an EME. Our structure enables us study the implications of Lender-of-Last-Resort (LOLR) policies in an EME and to add some new insights over the (stylized) closed economy results of Goodhart and Huang (2005) and Rochet and Vives (2004). A contribution we make to the literature, is that with no interventionist policies such as LOLR designed to bailout the crisis-catalyst bank, a crisis in the banking sector will never spread to the foreign exchange market and that the Central

Bank will always have enough dollars to fund those running on the bank. However, with foreign exchange reserves designed for the twinned task of defending a soft peg and of bailing out an illiquid bank, we show that a banking crisis may result in a currency crisis under certain parametric restrictions. These parametric restrictions are documented in the main text and must be fulfilled in order for a banking crisis to lead to a currency crisis. The idea is intuitive: when a crisis occurs at a bank, LOLR measures designed to rescue it may siphon off the dollar reserves of the Central Bank. If the Central Bank runs out of reserves, it has no option but to withdraw from the foreign exchange market and let the currency be dictated by market forces (currency crises).

In a similar line of thought as in **chapter 5**, an interesting issue that we pioneer is the notion of *'intertemporal substitution of banking crisis'* in a multi-bank setup with several periods. We conjecture that, if a Central Bank intervenes with its LOLR measures at a crisis-catalyst bank (information-induced), that intervention may drain the foreign exchange reserves of the Central Bank and may lead to a currency devaluation which, in turn, may affect otherwise healthy banks characterised by liability dollarisation in the economy. Thus, attempts to solve an information-based bank run in an emerging market economy characterised by liability dollarisation, may lead to a devaluation-induced banking crisis in other banks in the economy. As a result, LOLR measures may have negative spillover effects throughout the banking system. We do a cost-benefit comparison of the welfare implications of intervening at a crisis-catalyst bank and we show that, through LOLR, the costs in terms of future devaluation-induced bank runs outweigh the benefits of resolving current information-induced bank runs. Thus, LOLR is suboptimal in emerging markets because it may create a contagious channel of its own. This finding is completely new to the literature and augments the closed-economy arguments of Goodhart and Huang (2005) and Rochet and Vives (2004) who argue that, under certain circumstances, Central Banks may not find it optimal to intervene with LOLR. The chapter ends by considering the effectiveness of crisis management measures like capital controls, in making financial systems more robust and resilient to financial crises. The aim of these state-contingent safeguard measures is to help avoid banking crises (and their associated spillover effects, where relevant) and to help restore the second-best solution that the Planner can achieve.

Chapter 8 considers a similar question but analyses the transmission process from currency crisis to banking crisis. As in the previous chapter, the banking environment is drawn from **chapter 6**. The innovative approach of **chapter 8** is in its modelling structure and in its implications for the government's public finance. Here, depositors of the banks are assumed to receive a perfect signal of the economy's *'shadow exchange rate'* (i.e the exchange rate that would have prevailed if the regime was a floating one). As we mentioned in the main text, our concept of 'shadow exchange rate' is different from that adopted by Flood and Garber (1984) in that we do not allow for time-variations in exchange rate. However, as in the previous chapter, we begin by assuming a credible soft peg. We augment the Allen and Gale (1998) framework by characterising depositors' equilibrium in terms of the 'shadow exchange rate'. In our knowledge, there are no papers in the literature that attempt to model devaluation – induced bank runs explicitly and **chapter 8** is intended to bridge this gap.

Here again, we use the mechanism design approach to show that a banking system allocation is weakly Pareto inferior to the planner's second-best solution when the shadow exchange rate cannot be observed. In the absence of a currency devaluation, the banking allocation coincides with that of the planner. But when such devaluation occurs with positive probability, the banking system allocation is strictly inferior to that of the planner.We then proceed to study the dynamics of the crisis (when devaluation occurs with positive probability) and the resulting potential transmission of a currency devaluation to the banking system. We show that there is a trigger equilibrium in the shadow exchange rate above which the currency is devalued (all depositors withdraw and a devaluation-induced bank run occurs) and below which the soft peg is maintained (depositors withdraw according to their true liquidity needs only and a devaluation-induced run is prevented). Thus, given this specificity, a devaluation always leads to bank runs in this model of an EME characterised by liability dollarisation. However, under what circumstances will a devaluation-induced bank run lead to a banking crisis ? We construct values for the banks' stochastic asset returns which will be necessary to preserve the balance sheet of the bank and that will successfully ward off the effects of a currency devaluation on depositors' decision to withdraw. We show, in a performance space similar to that of **chapter 5**, a range of the banks' idiosyncratic fundamentals in which a currency devaluation will always lead to a banking crisis when no such crisis would have existed otherwise. A natural consequence of a currency devaluation in this setup, is that it may lead to contingent liabilities for the government if the latter needs to intervene in some states in the world in which a devaluation results in a banking crisis. The chapter ends by conjecturing the implications of these contingent liabilities for the design of an optimal bailout scheme fully funded by a tax system.

The last parts of **chapters 7** and **8** study the design of prudential policy options for EME. We come with certain proposals that have so far not been identified in the literature but, which we believe, are crucial given the findings of our framework. One of the appealing features of our paradigm is that it is rooted in microfoundations of financial intermediaries. As a result, we can contribute in a novel way to the debate on the design and choice of exchange rate regimes in EMEs, based on the ability of the system to minimise the likelihood of banking and currency crises (twin crises) occurring. This departs radically from the current macroeconomic paradigm that makes the choice of exchange rate regimes, a function of the ability to control and mitigate some exogenous factor, say, inflation. Why is the choice of exchange rate regime important for an EME ? Our model has two opposing forces that, according to the conventional macroeconomic paradigm, have contrasting effects on the choice of exchange rate regimes. On the one hand side, our banking system is characterised by financial liberalisation i.e is well integrated in world financial system in that all depositors are foreign investors. Financial liberalisation warrants a flexible regime since a fixed regime would lead to unnecessary speculative pressures on the currency and lead to monetary sovereignty loss . On the other side, our banking system is characterised by liability dollarisation. This warrants a fixed exchange rate regime due to the 'fear of floating' argument. Due to these contrasting effects, conventional macroeconomics will fail to offer any suggestions about the appropriate design of an exchange rate regime.

We endeavour to contrast the effectiveness of different scenarios, depending on the aim of the policymaker. In particular, our model suggests that if the aim of the policymaker is to keep exchange rate stable, it may do so by using interest rate policy rather than foreign exchange reserve policy to defend the peg. While both forms of policy intervention succeed in keeping the exchange rate fixed, they do so at the cost of destabilising the banking system. Using interest rate to keep the exchange rate fixed may keep the exchange rate stable, at the cost of triggering an information-induced bank run if interest rate fluctuations affect a bank's idiosyncratic fundamentals. Using foreign exchange intervention to keep the exchange rate fixed may achieve the same aim, at the cost of draining reserves and of eventually leading to future devaluation-induced bank runs. Since we show that an information-induced bank run is less costly than a devaluation-induced bank run, it follows that managing a fixed exchange rate system in an emerging market economy, is better achieved by using interest rate rather than foreign exchange reserves.

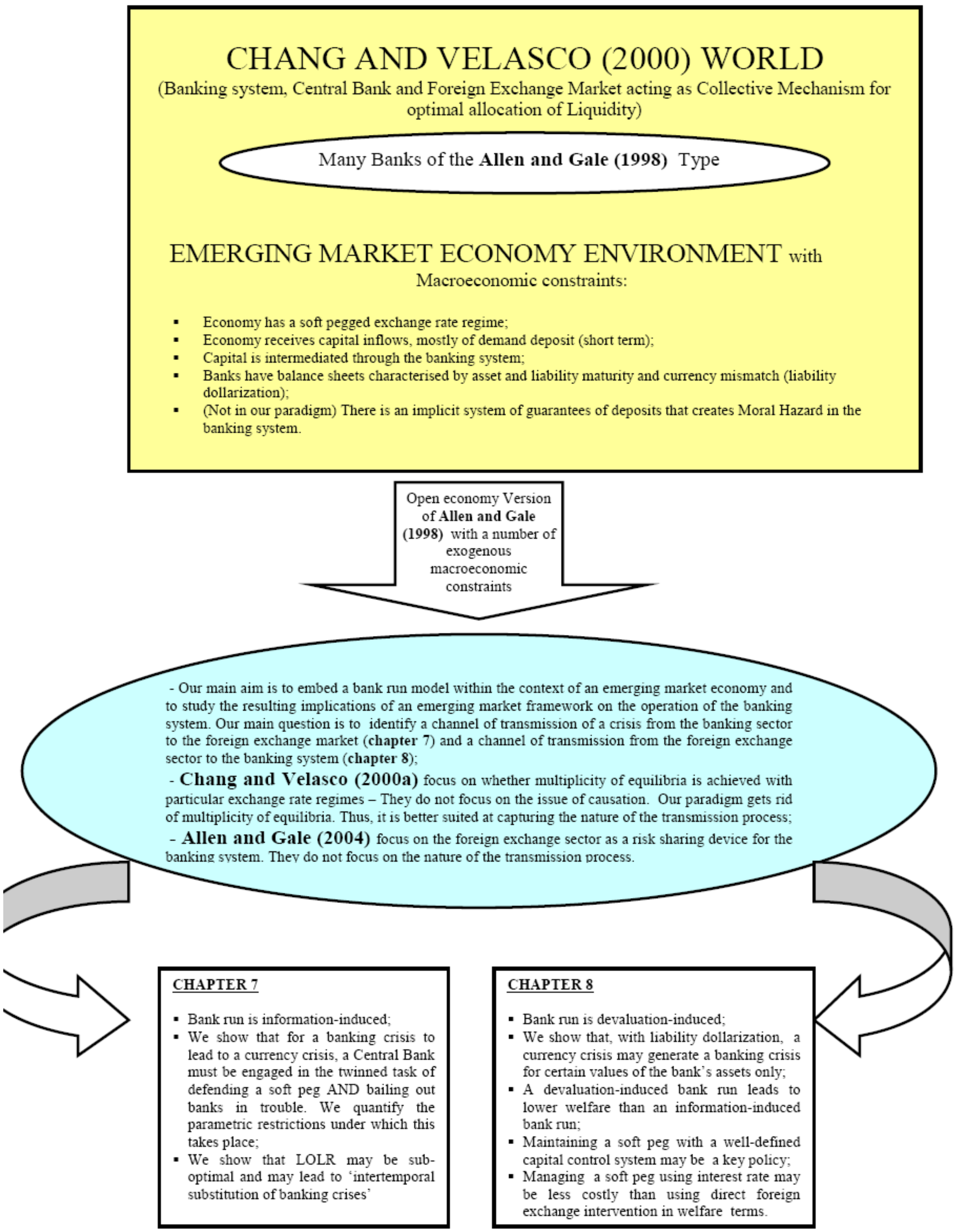
If the aim of the policymaker is to pre-empt the occurrence of banking crisis, it may adopt a fixed exchange rate regime juxtaposed with appropriate capital controls as way of ensuring stability of banking system. While this measure succeeds in preventing a banking crisis, it may not necessarily replicate the Planner's Second-Best solution. We show that the ability to generate the Second-Best solution of the Planner, depends on the order in which depositors have presented themselves to the bank. Conversely, if the policymaker wants to design an exchange rate regime that has an imbedded mechanism to thwart both crises (i.e eliminate the likelihood of both crises), some state-contingent structure in the exchange rate regime is important. The aim of the state-contingent structure is to enable restore the Planner's Second-Best allocation. A few propositions are studied e.g state-contingent crawling peg systems, state-contingent capital controls, managed floating regime.

The last chapter, **chapter 9**, concludes the thesis. **Chapter 9** summarises the main findings of all chapters of this thesis and points out all the new contributions to the literature. Our main contributions are duly explored and a contrast is made with the existing banking crisis models in the literature. Some limitations of our approach are highlighted and potential avenues for future research work are mentioned as well.[The pictorial representations on next couple of pages (Figures 1.4 and 1.5) shows the essence of the build-up of the paradigm constructed in **chapters 6, 7** and **8**. The specific questions we are trying to answer and our exact contributions to the literature, are also provided].

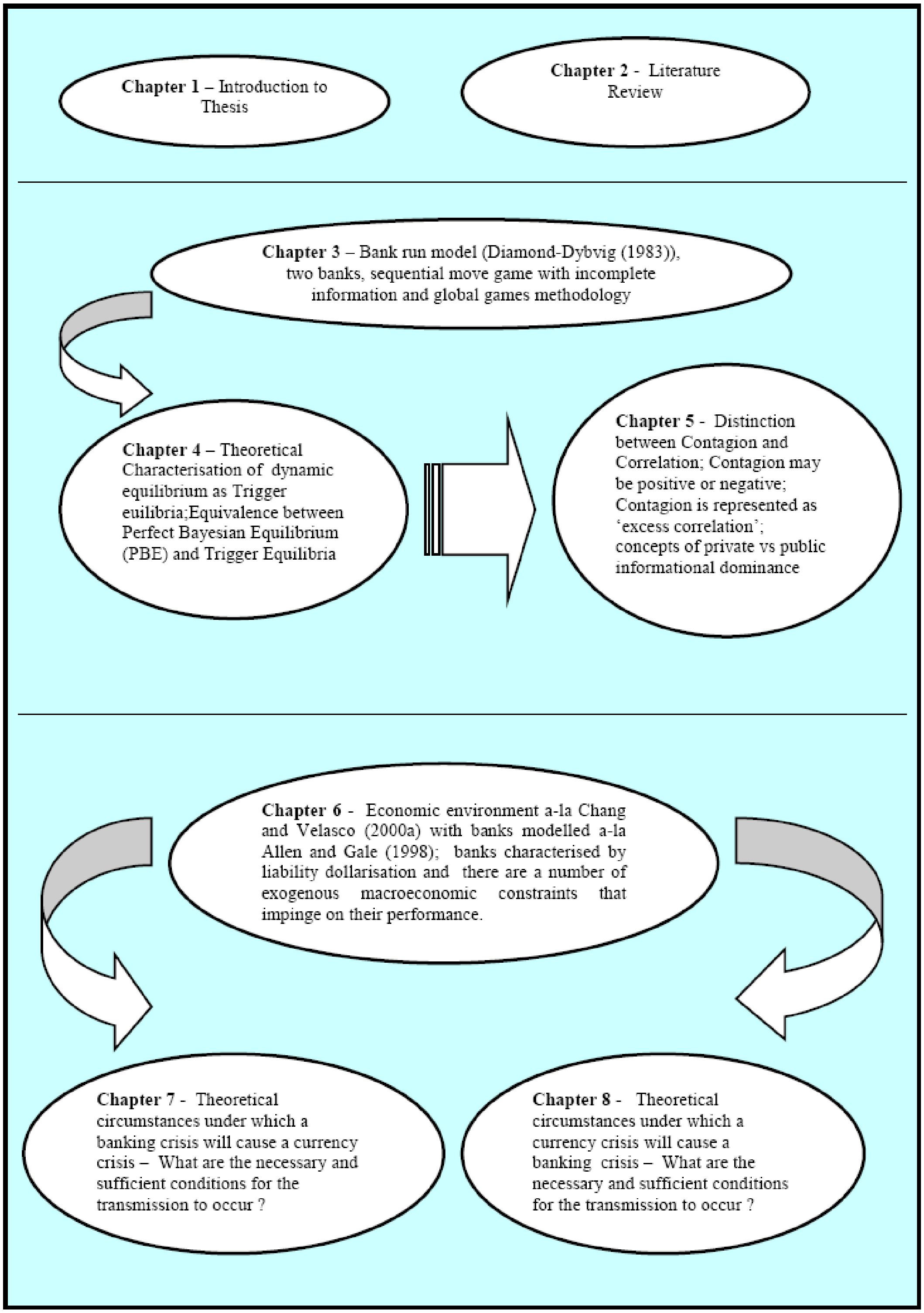
FIGURE 1.4: Key Questions and Answers (Chapters 6, 7 and 8)

SECOND QUESTION - Using the mechanism design approach, how to build a model of banking crisis in an Emerging Market Economy (EME) that:	**Our Approach, Methodology and Findings**
▪ provides an interpretation of how the operation of the banking system will be affected by the exogenous macroeconomic constraints imposed by an EME	=>Embed an Allen and Gale (1998) banking system within a Chang and Velasco(2000a) setup with some EME constraints: **[1]** *Soft Pegged Regimes* **[2]** *Financial Liberalisation* **[3]** *Short term Inflows* **[4]** *Liability Dollarisation* **[5]** *Guarantee System* (**Chapter 6**)
▪ offers a welfare-theoretic interpretation of banking crises	=> Banking allocation is Pareto Inferior to that of Planner using mechanism design. With no runs, banks offer insurance against liquidity shocks but not against aggregate shocks, with the result that there is a state-contingent term structure of payments to depositors. Bank runs occur with positive probability (**Chapters 7 and 8**)
▪ provides a theoretical analysis of the circumstances under which a banking crisis will lead to a currency crisis	=> Bank runs are informational-induced. Development of parametric restrictions for showing this link when there is Lender-of-Last Resort (LOLR). Through *'Intertemporal Substitution of banking Crisis'*, LOLR is sub-optimal (**Chapter 7**)
▪ offers new insights on nature of policy interventions for banking crises in an EME	=> Policy measures are intended to replicate the Planner's Second-Best allocation. If LOLR is suboptimal, how effective are measures such as Capital Controls ? Existence of Paretian ranking (**Chapter 7**)
▪ provides an analysis of the circumstances under which a currency crisis will lead to a banking crisis	=> Devaluation leads to bank runs but a banking crisis can still be avoided for a specific range of stochastic idiosyncratic fundamentals. Proof that devaluation-induced bank runs lead to higher welfare loss than information-induced bank runs (**Chapter 8**)
▪ contributes to the debate about choice of exchange rate regime based on fragility of financial systems	=> Choice of Exchange Rate regimes: **[1]** Soft Peg with Capital Controls ? (**Chapter 7**) **[2]** Interventionist Policies for Central Banks: Interest rate vs foreign exchange intervention ? (**Chapter 8**) **[3]** State-Contingent Crawling of Adjustable Pegs ? (**Chapter 8**) **AIM:** Minimise welfare loss for underlying banking system by the adoption of these policies.

FIGURE 1.5: Illustration of Chapters 6, 7 and 8 - What is New in our Approach and What is Our Contribution to Knowledge ?



1.2 How do the Chapters Link ?



Chapter 2

General Literature Review

2.1 Introduction[1]

There is no "one-size fits all" definition of what constitutes financial instability. Many observers will view a financial system as being stable if it shows much resilience and ability to resist a crisis due to a shock to either one institution within the system or to the whole system, within which all institutions operate. The pitfall with this doctrine is that financial instability is merely viewed as an *"egg from which crises are hatched"* – what "resilience" and "ability to resist a shock" mean, are not carefully defined. Thus, this stripped-down version is primarily viewing financial instability from the vantage point of a financial crisis. From this perspective, any systemic event that causes economic loss of value that is strong enough to cause serious disruption to real economy, will be categorised as instability.

Haldane, Hall, Saporta and Tanaka (2004) argue, such a definition ignores the other possible ways financial instability may manifest itself. They argue that three non trivial issues would be absent from such a narrow perspective:

[1] The literature review section of this thesis originally circulated as a document entitled: "Financial Systems, Micro-Systemic Risks and Central Bank Policy: An Analytical Taxonomy". Please refer to Moheeput (2005) for more.

[**1**] the initiator of a crisis; [**2**] the propagator of the crisis and [**3**] the existence of financial frictions which magnify the amplitude and frequency of crises, in a way that systematically alters the dynamic path of the economy. Haldane et al (2004) propose a holistic version of financial instability that nests the notion of a crisis within these three issues. If the essence of a financial system is to allocate resources efficiently across time, across states of nature and to ensure smooth and efficient financing of investment projects and efficient pricing of risk, then a financial system will be viewed as financially stable if it guarantees the fulfilment of these functions, even in the presence of a shock. Financial fragility will thus be viewed as one in which one or more of these functions become dismantled, due to shocks to the system. In the presence of financial frictions, these shocks alter the dynamics of a crisis and give well defined shape to its anatomy.

This holistic version of financial fragility encompasses the analysis of systemic risks involving financial intermediaries or banks. There are two aspects of systemic risk that the literature identifies: microsystemic risks and macrosystemic risks. The former can be defined[2] as: *"risks to the financial system that occur when the interaction of a bank with other banks or with financial markets, can propagate an initially localised shock to the whole financial system, by subjecting the derived analytics of the crisis, as an endogenous part of the theory"*. It is this particular form of systemic risk with which we are concerned in this chapter. The difference between the different interacting units that make up the financial system is important and any macroeconomic variable is taken as given or fixed. Macrosystemic risks, on the other hand side, can be defined[3]: *"risks occurring when, through the presence of financial frictions or imperfections, a financial system's interaction with the macroeconomy, can magnify the frequency and intensity of crises and have a more entrenched impact on key macro variables (e.g real business cycle) "*. With macrosystemic risks, the difference between different financial intermediaries is immaterial. It is thus theoretically

[2] Quoted from Moheeput (2005)

[3] Quoted from Moheeput (2005)

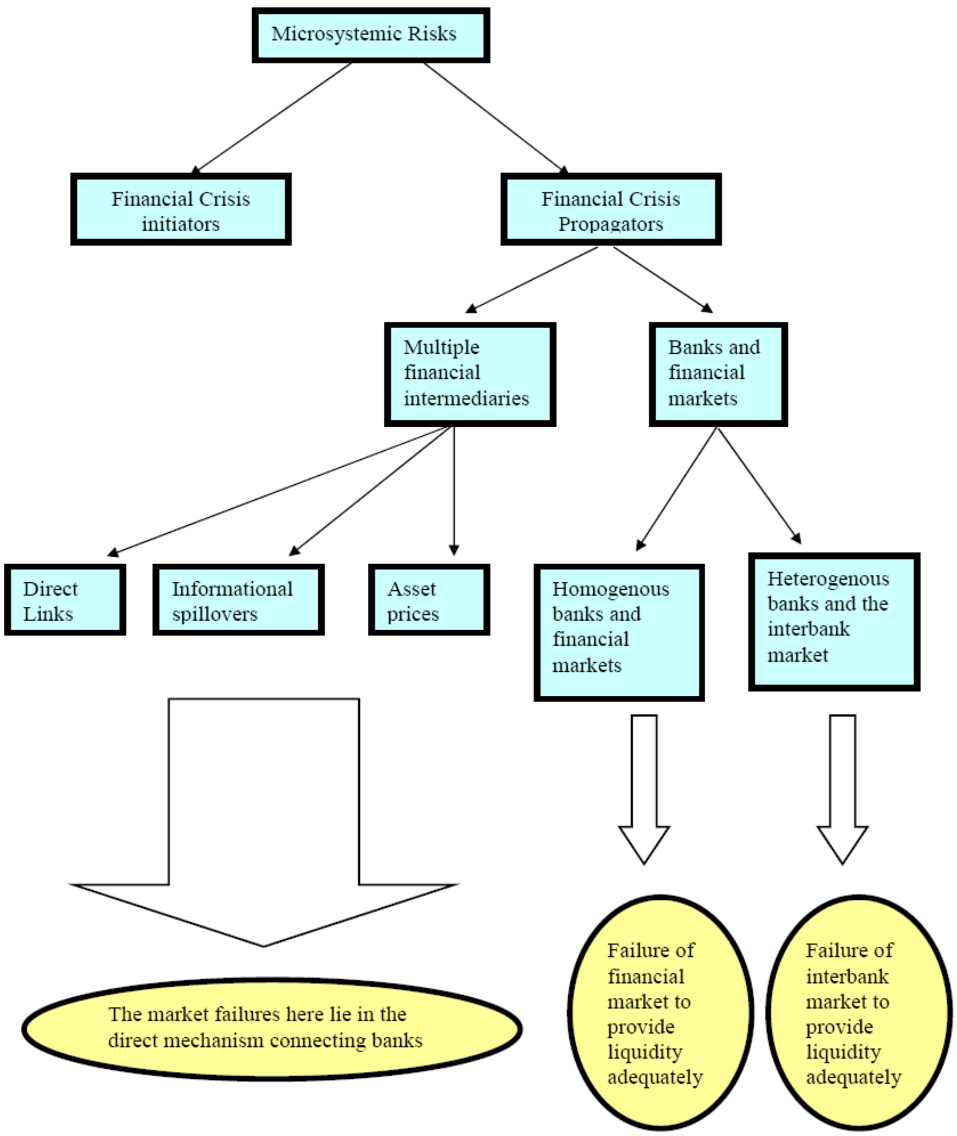
possible to consider financial intermediaries as a single unit. What matters is the impact that financial intermediation has on macroeconomic variables and how, the presence of financial frictions can affect macroeconomic variables .

The need to mitigate systemic risks in a financial system is one of the most important reasons behind the enactment of prudential banking regulatory policies. Measures may be implemented either ex-ante, as part of systemic-risk prevention or ex-post, as part of systemic-risk management. While the former concerns the institution of rules or standards that makes the financial system more "crisis-proof", the latter concerns the instigation of policy measures to stall a crisis once the symptoms of its occurrence start to appear. It is worthwhile mentioning, though, that policy measures designed to stall a systemic crisis, are not without pitfalls. While they may be benign in preventing the fully blown impact of a system-wide crisis on output and on financial intermediation, they may cost a lot in terms of taxpayers' money and have an adverse impact on incentives of key stakeholders in the financial system.

Thus, if the costs of preventing a system-wide crisis are higher than the costs that the banking crisis entails to output and intermediation, then the case to regulate or impose policy measures, becomes weak. To be able to assess this cost and benefit of policy mitigation in a systematic way, we need a framework that juxtaposes both issues in one setup and that assesses the net benefit of policy measures in a welfare-theoretic sense. Fortunately, microeconomic analysis is helpful at providing that insight and helps assess how successful different policy measures are at tackling system-wide risks and whether they help restore the First-Best allocation of resources.

Figure 2.1 (please turn over for illustration) provides a pictorial synopsis of the approach we intend to adopt throughout the rest of this chapter. Following the aforementioned definition for microsystemic risks, this chapter is organised as follows: we initially start with financial crisis initiators. Here, the literature for financial fragility and coordination failure for the one-bank case, is reviewed

FIGURE 2.1: Roadmap of Microsystemic Risks Taxonomy

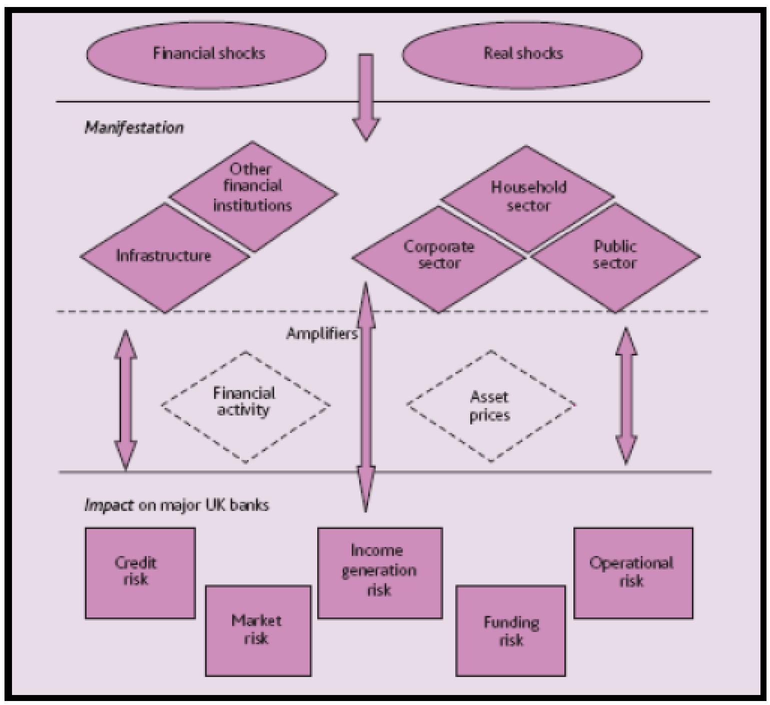


in **section 2.2**. Because models of systemic risks involving bank runs, almost always start with a technological or liquidity shock occurring at one bank, it is useful to have an overview of the implications of this literature for policy mitigation. We then deal with propagators of a crisis. Here, we go beyond the confines of the one-bank scenario to include cases involving multiple banks (**section 2.3**) or involving an interaction between banks and financial markets (**section 2.4**).

In these models, there exist several avenues through which a bank failure may spread to other banks. Banks are often connected through the existence of overlapping financial contracts such as the interbank market in deposits or loans. Sometimes, they can interact with financial markets as well. In the absence of market failures, the interbank market or the financial market will allocate resources efficiently. Cash-strapped banks will always be able to get their way out of liquidity troubles. If markets failures exist though, liquidity provision by the interbank market or by financial markets in general, may be inadequate. The illiquidity problem at one bank may contagiously spread to other banks connected to it through financial contracts or the illiquidity problem may turn into an insolvency one. In both cases, the existence of market failures will warrant a case for Central Bank intervention as a way of mitigating these crises amplifications. It is the purpose of this chapter to categorise the literature therein, unearth the market failures responsible for the crisis propagation and assess how successful policy measures are in mitigating micro-systemic risks. **Section 2.5** summarises the literature for macro-systemic risks. Finally, **section 2.6** concludes for **chapter 2**. Figure 2.1(b) (please turn over for illustration) illustrates a systemic risk transmission map for the UK economy, as depicted in a Bank of England report[4].

[4] Bank of England (BoE) Financial Stability Report, July 2006, Issue 20, pp 46.

FIGURE 2.1 (b): Systemic Risk Transmission Map (UK economy)



2.2 Liquidity Insurance Provision

Financial systems (incorporating financial markets and financial intermediaries such as banks) play a fourfold-role in the economy (Allen and Gale (2003)): they channel savings from where they are in excess to where they are in need; they allow for intertemporal smoothing of consumption by households and expenditure by firms; they provide intratemporal insurance against liquidity shocks to households and firms by enabling them to share risks; they allow for the efficient financing of profitable investment projects.

Ever since the special critique of Fama (1980) about the specialness of banks or financial intermediaries as to their relevance in an Arrow-Debreu setup, a huge body of the literature has surged, validating the role of banks by stressing on their role in alleviating different forms of market imperfections (Freixas and Rochet (2002)). As dealers in non-marketable financial contracts of different forms, the nature of a bank's activities exposes it to panics or runs, which occur mainly when depositors, fearing that the bank will be unable to meet its contractual obligations, decide to withdraw their funds from the bank. Bank runs remain an accute issue today. While Europe and the United States have experienced a large number of bank runs in the 19th century and beginning of the 20th, many emerging markets have experienced severe episodes of banking crises in recent years. Latin America seems to suffer from these episodes once every decade (Chile (1980s), Argentina (mid 1980s, 2002), Mexico (mid 1980s). Other spectacular accounts of banking crises include the South East Asian flu (1997) and the banking distress that plagued the Eastern European countries (Baltic countries (1992), Bulgaria (1997)). As Gorton and Winton (2002) note in a recent survey on financial intermediaries, even countries that have never experienced bank runs strive hard to pre-empt the likelihood of a banking crisis from developing by adopting tough lines on regulatory measures, the costs of contagious effects of banking crises in terms of loss output, financial dis-intermediation, dismantling of the payments / settlement system and public outlays needed to revamp the banking system, being far too high.

Banks act as intermediaries between firms that are cash-strapped and that need to borrow (issuers of financial securities) and investors, who have excess cash and who wish to part with that excess liquidity temporarily (recipients of financial securities). The nature of a bank's activities means that it is linked to its stakeholders through heterogenous contracts. The features that these contractual arrangements have for the bank's balance sheet, are categorised as follows:

[**1**] Maturity mismatch - assets (e.g loans) are illiquid and liabilities (e.g deposits) are liquid.

[**2**] Liquidity-profitability mismatch - the more illiquid the assets, the higher the return on the asset.

[**3**] High gearing and relatively low capitalisation - deposits being very high relative to equity.

[**4**] Creditors (i.e. depositors) are actually the bank's clients.

These features distinguish a bank from a number of other institutions and expose it to an array of risks . Consumers deposit their endowments in the bank but face uncertainty about the timing of their consumption. The problem that banks face is to try to match the structural features described above with the uncertainty about the timing of consumption by depositors. By offering demand deposit contracts, they can do that. Since the work of Diamond and Dybvig (1983) on bank runs and liquidity provision, there has been a surge in the literature of bank runs and on panic transmission. Diamond and Dybvig (1983) contributed significantly to our understanding of banking activities because their seminal work was to analyse bank failure from the intrinsic characteristics of a bank's balance sheet, as detailed above.

In this model, banks are seen as intermediaries that accept deposits from households, pool these resources and invest them in technologies to which depositors individually do not have access to, and offer depositors a better combination of returns and liquidity services. The bank offers depositors demand deposit contracts that basically allow depositors to withdraw their deposits to meet any pressing liquidity needs.

Coordination failure has been rationalised as potential explanation for the behaviour of depositors. In a setting with the existence of a storage technology, a long term asset that can be liquidated prematurely and a sequential service constraint, each depositor of a given bank is concerned with what other depositors of the same bank are doing. Thus beliefs about each other's actions become important in decision making. This belief generated mechanism has a strong self-fulfilling element, such that multiple equilibria results.

The model of Diamond and Dybvig (1983) is as follows: There are three periods, time 0, 1, 2. In time 0, depositors invest their endowments in the bank. The latter invests the endowment in a short term liquid technology and a long-term illiquid technology and offers a demand deposit contract that depicts the amount the depositor will receive, following withdrawal of deposit. The illiquid technology yields a non-stochastic return of R in period 2. If liquidated prematurely (i.e time 1), it yields a return of r (< 1), thus representing a cost involved in early liquidation. There is also a short term liquid technology which yields a return of 1 (for every unit of endowment invested therein). Depositors are assumed to face a liquidity shock in period 1, which is independently and identically distributed among depositors. With probability λ, they may be impatient (i.e wish to consume early) and probability $1-\lambda$, they may be patient (i.e wish to consume late). The distribution of liquidity shocks is common knowledge, but the private realisation of the liquidity shock is private knowledge.

To see the improvement in consumption allocation, it is important to make a contrast between the three: in autarky, each individual is bound by his budget constraint and the absence of any markets whatsoever, means that he consumes less or equal to 1 if he is an impatient consumer and less or equal to R if he is a patient consumer. With a financial market allowing for the possibility of trading assets, a consumption stream of $(1, R)$ would be possible. Thus if the individual is impatient, he will sell his holdings of the long asset and consume the proceedings. If he is patient, he use the amount invested in the short technology to buy assets, which he can hold until period 2. Given equilibrium price for the financial asset, it can be seen that the market allocation coincides with the uppermost allocation, namely $(1, R)$. This represents a Pareto improvement over the autarky but has a setback. At period 0, each agent would prefer a consumption plan that trades some period 2 consumption for period 1 consumption. Thus, agents would like to receive some insurance against the risk of being impatient. The financial market cannot offer perfect insurance against the risk of being an impatient consumer. The rationale is that the set of markets being allowed for is incomplete. There is no market for contingent claims, on which the individual can trade liquidity for delivery in the interim period, contingent on his type.

Financial intermediaries can be seen to fulfil that liquidity insurance role, through demand deposit contracts. The crucial point is that, while individual depositors face the uncertainty in period 0 as regards their liquidity needs, a bank does not face such uncertainty. By the Law of Large Numbers (LLN), these idiosyncratic liquidity shocks will be mutualised and the proportion of early (late) withdrawals that the bank will face is exactly equal to λ ($1 - \lambda$ respectively). Thus, if the bank follows a fractional reserve system, it becomes clear that it will earmark a proportion of λ of deposits to the short asset and a proportion of $1 - \lambda$ to the long asset. These results are summarised in Figure 2.2 (turn over for an illustration).

If the bank faces excess early withdrawals (i.e withdrawals that cannot be met by the short assets alone), it will be forced to liquidate the long asset in period 1 in order to provide for the liquidity needs of those who withdraw early. Patient depositors know that since the long asset is liquidated, they may get

FIGURE 2.2: Consumption Profiles under Different Institutional Regimes

Institutional Regime	**Consumption in period 1**	**Consumption in period 2**
Autarky	≤ 1	$\leq R$
Financial Market with equilibrium price for financial asset traded	$= 1$	$= R$
(Diamond and Dybvig (1983) setup) Financial intermediary offering fixed demand deposit contract (Coefficient of relative risk aversion >1)	> 1	$< R$
Financial intermediary offering fixed demand deposit contract (Coefficient of relative risk aversion <1)	< 1	$> R$
Financial intermediary offering fixed demand deposit contract (Coefficient of relative risk aversion =1)*	$= 1$	$= R$

Note:

The optimal consumption profile in the Diamond and Dybvig (1983) set-up (first best) matches that of the financial market, in the situation in which the coefficient of relative risk aversion for depositors is equal to 1. In all other cases, there is a deviation of the financial market from the first best allocation.

a lower amount than promised by the demand deposit contract. They may therefore all have an incentive to withdraw early, thereby prompting a run on the bank .

2.2.1 Policy Implications in Liquidity Insurance Models

Banks offering fixed demand deposit contracts achieve the optimal risk-sharing allocation. But such a contract is very much susceptible to runs by cohorts of depositors, for reasons that have to do with extraneous variables (or sunspots), not explained within the model. In the case of runs, the allocation is inferior to autarky. This trade-off between efficiency and stability that is inherent in the Diamond and Dybvig (1983) setup, has prompted research into possible ways to achieve the optimal (first-best) solution, whilst mitigating financial instability. Possible reform proposals have ranged from institutional reforms (as ex-ante measures) and specific governmental policy measures like deposit insurance (as ex-ante measure) or suspension-of-convertibility (as ex-post measure).

Institutional reforms concern the re-designing of the features of a bank's balance sheet, so that, it no longer faces the dangers of financial instability. If, through demand deposit contracts, banks become fragile once they face large premature withdrawals, one important remedy would be to try to match the bank's structural features to the statistical predictability of the time pattern of withdrawals. The concept of 'narrow banking' does exactly that. With narrow banks, the maturity structure of assets is perfectly matched with the maturity structure of deposit contracts. Thus, the amount that the bank earmarks to the short liquid asset (e.g its reserves), is sufficient enough to meet payments to depositors, should they all decide to withdraw early. This form of institutional arrangement can help to prevent bank runs, but it does not achieve the optimal risk-sharing allocation. As Wallace (1988, 1996) argues and quoted by Freixas and Rochet (1997), the solution to the optimisation problem for the narrow bank is even dominated by that of autarky or that of a bank engaged in maturity transformation.

Government regulatory response may take the form of deposit insurance schemes or suspension-of-convertibility. Deposit insurance basically concerns the scheme designed to protect the interests of depositors, in the face of bank runs. Depositors are too small and diverse to be able to monitor the performance of bank managers. Furthermore, they may face high monitoring costs. This means that, left on their own, there will be an incentive for depositors to free-ride on each others' attempts to monitor. The resulting underestimation of monitoring, means that there must be some agency to look after depositors' interests, in case of bank failures. There are still questions in the literature surrounding the design of the most appropriate deposit insurance scheme . Suspension-of-Convertibility (SOC) concerns the formal prohibition of the bank to serve more than a certain threshold of proportion of early withdrawals. By preventing the long asset from being liquidated or traded, it guarantees that a certain amount is still available for payment in the final period. The actual results are subsumed in Figure 2.3 (please turn over for an illustration).

The effectiveness of deposit insurance and SOC depends crucially on whether there are aggregate risks (about the aggregate proportion of early withdrawals) or not in the setup. In the absence of aggregate uncertainty, they achieve the same results: they both eliminate the possibility of having bank runs and help maintain the optimum outcome. With aggregate uncertainty, the equivalence between the two schemes break down. SOC still eliminates bank runs, but it is not efficient as a risk-sharing instrument. The reason is that, with uncertainty about the pattern of aggregate withdrawals, there may be either of the following two scenarios: if the proportion of early withdrawals is too high compared to the threshold for SOC, those withdrawing early will be rationed and get a smaller amount than has been promised. If it is too low, it means that those deciding to withdraw in period 2, are too numerous, and again, will receive less than has

FIGURE 2.3: Policy Implications – Summary

	Specific nature of reforms	**Elimination of bank runs ?**	**Do we get First-Best (risk-sharing) allocation?**
Institutional Reforms	Narrow Banking	Yes	No
Contractual Reforms	- Equity contracts? (Jacklin, 1987), (Jacklin and Bhattacharya, 1988)		
	- Make contracts more flexible? (Peck-Shell, 2000)		
Policy Measures			
(No Aggregate Uncertainty)			
Suspension-of-Convertibility (SOC)		Yes	Yes
Deposit Insurance		Yes	Yes
Policy Measures			
(Aggregate Uncertainty)			
Suspension-of-Convertibility (SOC)		Yes	No
Deposit Insurance		Yes	Yes

been promised. In other words, SOC does not allow for contingent allocation. Deposit insurance, on the other hand, makes allocations contingent on aggregate shocks. In the special case in which the deposit insurance scheme is publicly run and financed by an appropriate tax system, the government can vary the tax rate based on actual realisation of early withdrawals, and achieve the optimal risk-sharing allocation.

2.2.2 Robustness of Liquidity Insurance Models

Thus, demand deposit contracts are seen to achieve optimal risk-sharing, but are also seen to be unstable. The natural question that comes to mind is: why are deposit contracts then issued by banks? Since Diamond and Dybvig (1983), the literature on bank runs has evolved and many different avenues have been explored in a way that literally helps to answer this question from different perspectives. Jacklin (1987), for instance, argued that equity contracts can sometimes do better than demand deposit contracts for certain specifications of the utility function. In this model, consumers are equity holders rather than depositors in the bank. Whilst achieving the same (optimal) consumption allocation as a deposit contract, these equity contracts are not susceptible to bank runs. The rationale is that equity contracts are coalitionally incentive compatible (i.e immune to withdrawals by coalitions of individuals) while deposit contracts are only individually incentive compatible . For more general specifications of utilities, deposit contracts dominate equity contracts, thereby unearthing the inverse relationship between efficiency and stability again. Other papers have endeavoured to rationalise the case for actual contracts taking the form of demand deposit contracts with the possibility of withdrawals on demand, rather than some other form (See Calomiris and Kahn (1991) and Diamond and Rajan (2001a)).

A trend of the literature on bank runs has also considered the “other view” of bank runs and have related the performance of the bank’s assets to the business cycle. These models allow the return on the long technology to be stochastic. This second view reflects empirical studies by Gorton (1988), Calomiris and Gorton (1991), which show that bank runs are not random events but intimately related to the business cycle. These models have important policy implications that help add a new dimension into our thinking as to how policymakers should effectively conduct policy.

Allen and Gale (1998) confirm the findings of studies by Gorton et al, by showing that the business cycle plays an important role in triggering banking crises. In a model in which the long technology is subject to stochastic returns and cannot be liquidated early, they show that bank runs are optimal in that they help achieve first-best optimal risk-sharing! Banks achieve the optimal outcome through offering fixed deposit contracts, with bank runs providing the optimal contingencies that help achieve first best result.

Another contribution which relates banking performance to business cycles is the one by Goldstein and Pauzner (2005). One of the setbacks of the Diamond and Dybvig (1983) framework, is that there is nothing within the model to explain what exactly triggers bank runs and coordination failure problems. The collection action problem means that each depositor is better off withdrawing conditional on other depositors withdrawing, even though, collectively, they would be better off if they did not withdraw. What drives these beliefs is not within the realm of the model and can be attributed to extraneous variables like sunspot phenomenon. Hellwig (2002) and Morris and Shin (1998) attribute this indeterminacy to two elements: common knowledge of fundamentals and higher order beliefs certainty. Goldstein and Pauzner (2005) are able to pin down unique equilibrium in models involving bank runs, using the global games approach. They find the endogenous probability of bank run occurrence and relate it to the demand deposit contract. By trading off benefits of risk-sharing vis-à-vis the probability of bank runs, they characterise the optimal contract and show that it does not achieve first best. By getting rid of the indeterminacy inherent in Diamond and Dybvig (1983), they argue that it is technically possible to compute the effectiveness of alternative policy measures. In other words, if the model is no longer silent about the probability of bank runs, it becomes convenient to estimate how successful different policy measures will be to preempt these runs.

Zhu (2001) develops a two-stage banking model in the same spirit as Goldstein and Pauzner (2005) and attempts to examine the welfare properties of policy mitigation. He finds that SOC is both ex-ante and ex-post inefficient in preventing bank runs because it cannot distinguish between those with true liquidity needs and those who are simply running on the bank. Thus, even if bank runs are prevented, it is likely that some agents facing true liquidity needs cannot withdraw their deposits, while those without true liquidity needs get their money back. Deposit insurance is ex-post efficient in preventing bank runs but ex-ante inefficient, due to moral hazard reasons. Because the deposit insurance authority cannot monitor bank's decision, banks have an incentive to behave opportunistically. The paper suggests that replacing full-coverage deposit insurance by interest-cap deposit insurance , can overcome the moral hazard problem and help the economy achieve socially optimal outcome. The imposition of capital requirements is an efficient way to prevent bank runs. As capital requirements increase, the market equilibrium converges to the socially optimum outcome.

Another trend has included moral hazard in models of bank runs. Since the work of Calomiris and Kahn (1991), in a setup that includes moral hazard and aggregate uncertainty, several papers have attempted to include moral hazard considerations in bank run models and explore the properties. Cooper and Ross (1998) attempt to examine the trade-off between risk sharing and moral hazard associated with the design of banking regulations. They show how regulatory instruments (like deposit insurance and capital requirements) can be used to control bank runs in an environment in which banks can act opportunistically by making imprudent investments and depositors can monitor the bank. Their paper is a synergy of similar work in the literature, including Matutes and Vives

(1996), Besanko and Kanatas (1993), Holmstrom and Tirole (1993). The main policy implications of the Cooper and Ross (1998) setup are as follows: in Diamond and Dybvig (1983), publicly financed deposit insurance can be effective as protection against expectations-driven bank runs. But moral hazard considerations are ignored. Deposit insurance avoids bank runs but has a two-pronged impact on incentives: on one hand, depositors are not willing to monitor the banks' performance and, on the other, bank managers are willing to act opportunistically in order to maximise the option value of the deposit insurance. By taking this moral hazard consideration into account, they characterise the trade-off that helps derive the optimal degree of deposit insurance. Complete deposit insurance is not sufficient to support the first best outcome, because depositors will not have adequate incentives for monitoring. This outcome can nonetheless be reached through a combination of policies. Capital requirements, when coupled with partial deposit insurance, can eliminate this incentive problem and help achieve the first best allocation again.

2.3 Models with Multiple Financial Intermediaries

Several episodes of financial crises are characterised by financial contagion among banks. The term financial contagion is taken here to mean, in broad terms, the spread of a banking crisis from one bank to another. The spread of a financial crisis from one bank to another can be through several channels. Contagious bank failures can be the result of either informational spillovers or contractual arrangements that connect banks or common exposure to some fundamental.

Informational externalities arise when depositors perceive the banks to be similarly affected, even though there may be no direct form of contracts that connect banks. Thus, depositors at one bank view the event taking place at another bank, and update their beliefs about their own bank, so that their bank shares the same fate as the first bank.

Contractual arrangements may take the form of direct links such as interbank market in deposits or loans or may take less explicit direct form links (e.g through asset prices or through the settlement / payment system). In the former case, banks engage in cross-holdings of interbank deposits as a way of insuring against regional liquidity shocks. When one region suffers a banking crisis, the other regions suffer a loss because their claims in the troubled region fall in value. If the spillover effect is strong enough, it can cause trouble to banks in adjacent regions. In the worst case scenario, the trouble may spread from bank to bank and, may indiscriminately, affect all banks in the economy. In the latter case, when there is excess demand for liquidity, banks liquidate their long assets and this drives asset prices down. This drop in prices cause some banks to go bankrupt and this leads to further sales and further price drops. Bankruptcy spreads through the market for long asset. If the magnitude of asset price fall is large, this may prompt a chain of multiple bank insolvencies. Even if the initial shock is small, the spillover effects through banks, may be cumulative and strong enough to warrant multiple bank failures.

Common exposures take the form of two banks being similarly and symmetrically exposed to the same fundamental. Hence, a change in the fundamental value will affect both banks, thereby prompting some form of ex-post correlation in their underlying asset. The concept of financial contagion has important implications for public policy activities of Central Banks as part of their crisis prevention and crisis management activities. More importantly, the multiple-bank setting involves aspects that spread beyond the confines of individual banks and that enable us summarise the resulting implications for Central Bank policy as follows:

[**1**] What is the nature of the dividing line between microprudential and macroprudential policy measures ?

[**2**] How effective are public policies in making the financial system more robust?

[**3**] How should central banks design the network structure underpinning

financial systems in a way that best makes the financial system resilient to shocks?

The sources of market failures responsible for transmitting a risk contagiously from bank to bank lie directly in the mechanism connecting the banks. Whilst this mechanism is responsible for channelling liquidity from liquidity-abundant banks to liquidity-strapped banks, it is also the channel through which trouble spreads in times of difficulties. Thus, the market failures directly responsible for spreading contagious risks are the externalities (and different forms they assume) that various channels create at times of trouble. It is important to note that, in this section, we will not be focusing on how market failures, per se, prevent the efficient workings of the various channels. This will be the focus of the next section.

2.3.1 Direct Link Models

Allen and Gale (2000) study a multiple bank version of Diamond and Dybvig (1983), in which banks are connected by an overlapping network of interbank deposit claims. The economy consists of a number of regions. The number of early and late consumers (who are assumed to have complete information about their environment) in each region fluctuates randomly, but the demand for aggregate liquidity is fixed. This opens the way for inter-regional insurance as regions with liquidity surpluses provide liquidity to regions experiencing liquidity shortages. The implication of constant aggregate demand for liquidity, is that regional liquidity shocks are negatively correlated across regions. While, in the interim period, some banks face excess demand for liquidity, others face excess supply of liquidity. In the subsequent period, the patterns for liquidity demands are reversed. One possible way of insuring against regional liquidity shocks is to engage in an ex-ante cross-holding of deposits through the interbank market. The interbank market is one way of implementing risk-sharing among banks.

While cross-holding of deposits are useful for reallocating liquidity within the banking system, they cannot increase the total amount of liquidity. If the total demand from consumers is greater than the stock of the short asset, the only way to meet this excess demand, is to liquidate the long asset. Allen and Gale (2000) show that, based on cost considerations, banks prefer to liquidate the short asset first, then their holdings of deposits in other banks and, lastly, their long asset. With the presence of an unanticipated aggregate liquidity shock (this condition has been shown to be necessary and sufficient for the analysis of financial contagion in the model), banks facing excess demand for liquidity, are forced to claim back their deposits held in other banks. If the amount received is small, the bank will be forced to liquidate its long asset to meet excess demand for liquidity. If doing so means violating incentive compatibility constraint (which technically makes returns to second period withdrawals higher than returns to first period withdrawals), there is a run on that bank and it may be forced into bankruptcy. Such an event reduces the equilibrium value of claims on that bank. Thus, other banks that hold deposits in it, will suffer a fall in their asset value. They may suffer from the same fate if this fall in asset value (i.e the spillover effect) is large.

Whether contagion occurs or not depends on the pattern of interconnectedness that shapes the interbank market structure. Allen and Gale (2000) assert the existence of three possible types of networks connecting banks: complete, incomplete or disconnected. A 'complete' network is one in which each bank holds claims on all other banks. An 'incomplete' interbank market is one in which banks hold deposits at banks in the adjacent region only. A 'disconnected' structure is one in which there may be no direct links between banks.

The incomplete interbank market is more susceptible to contagious effects than a complete interbank network. A complete network would ensure that the spillover effects of bank failure in one region evenly spreads out to all banks in other regions. Thus, a given size of unpredictable aggregate liquidity shock, is distributed uniformly across all banks. The greater the number of banks, the more spread out the spillover effects will be, and the greater will be the ability of the banks to meet uncertain liquidity shocks, without prompting bank runs. An incomplete network achieves the opposite results. The spillover effect becomes larger as the crisis spreads from one bank to another. The larger the number of banks, the larger will be the spillover effects. Contagion will inevitably occur in this realm. If banks are disconnected, the spillover effect is thwarted and does not affect the value of claims in other banks. No contagion occurs.

Robustness and Policy Implications

Various attempts have been made to test the robustness of the Allen and Gale (2000) model with varying degrees of success. Dasgupta (2004) uses the global games approach to study a two-bank version of contagion. In his setup, banks invest in a long term technology that yields a stochastic return (i.e one that is dependent on some independently and identically distributed fundamental). Depositors are assumed to observe the idiosyncratic fundamental of their bank with some noise and the timing in terms of decision-making is assumed to be structured and dynamic:

Depositors at one bank make their decisions before depositors of the other. In addition, in period 1, the banks face a regional liquidity shock that is negatively correlated across banks. In the spirit of Allen and Gale (2000), banks cross-hold a fraction of their deposits, in period 0, as a way of insuring against these regional shocks. Thus, given the realisation of the regional liquidity shock, the bank facing high withdrawals will claim back its deposits from the bank facing low withdrawals. Thus, there is a spillover effect in that, the value of one bank's deposits in the other bank depends on the financial performance of the other bank . As in Allen and Gale (2000), this provides the mechanism that propagates a crisis from one bank to the other.

FIGURE 2.4 – Dasgupta (2004) vs Allen and Gale (2000)
(Both models assume several banks connected through the interbank market in deposits)

Allen and Gale (2000)	**Dasgupta (2004)**
Banking panics occur due to Aggregate liquidity shocks (necessary and sufficient conditions for Contagion to occur)	No Aggregate liquidity shocks required for Contagion. The only requirement is adverse information about asset returns
Financial Contagion occurs with zero probability	Financial Contagion occurs with positive probability (endogenously derived)
Network architecture matters – Contagion is a function of the pattern of connectedness of banks in the interbank market. - Complete network : No contagion - Incomplete network: Contagion occurs	Network architecture is irrelevant - Contagion occurs with positive probability, even with complete network structure in the interbank market

Figures 2.4 highlights the main lines of contrast between Dasgupta (2004) and Allen and Gale (2000). Exposure through the interbank market means that, while the degree of regional insurance against liquidity shocks is higher, the possibility of having contagious flows is also higher. The intensity of contagion increases with the size of interbank connections, provided by the ex-ante cross holdings of deposits. Figure 2.5 (please turn over for illustration) highlights the main differences between Dasgupta (2004) and Goldstein and Pauzner (2005).

Dasgupta (2004) shows that it is not necessary to have unanticipated liquidity shocks for contagion to exist as an equilibrium phenomenon. This goes against the philosophy of Allen and Gale (2000). Furthermore, he shows that, with the interbank market providing ex-ante liquidity insurance against regional shocks, the structure of connections, spanned by the interbank market, does not matter. Even with complete markets, contagion may still occur as an equilib-

FIGURE 2.5 - Dasgupta (2004) vs Goldstein and Pauzner (2005)

Goldstein and Pauzner (2005)	Dasgupta (2004)
One Bank	Several Banks connected through the interbank market in deposits
Optimal Contract for deposits:	**Optimal Contract for Interbank deposits:**
Characterised by trade-off between risk-sharing and positive probability of bank runs (contracts offering better insurance also increase likelihood of runs)	Characterised by trade-off between insurance against regional liquidity shocks and positive probability of contagion
Result:	**Result:**
Optimal contract offers less than full risk-sharing because doing so would be too destabilising	Optimal interbank deposit contract offers less than perfect insurance against regional liquidity shocks

rium event.

It is interesting to point out how the two models vary in terms of their implications for welfare and use of policy for mitigating contagious risks. As ex-ante measures, Allen and Gale (2000) suggest the reform of the network architecture connecting banks. Since the complete network is more robust at mitigating the spillover effect than the incomplete network, it is highly suggestive for policymakers to ensure that the structure of overlapping interbank claims is as complete as possible. By preventing contagion, the appropriate design of the network system guarantees that the first-best allocation is reached. A similar conclusion is reached by Freixas, Parigi and Rochet (2000). In this model, the source of uncertainty is assumed to be 'location shocks' i.e ex-ante, depositors are unaware as to where they should consume. It is only in the interim period (i.e period 1) that they will know the nature of this location shock. Decisions to withdraw are made in period 2. The network connecting banks depends very much on the pattern of travel. There are two travel patterns in the setup: a 'credit chain lending' pattern and a 'diversified lending' pattern. The paper also investigates the robustness of the different types of travel patterns to the possibility of contagion. The diversified lending pattern is shown to be more robust and less susceptible to contagious effects than the credit chain pattern.

With a credit chain pattern, the credit risk is concentrated on a few banks only. Thus, while a few banks take the hit, the effect at individual bank level may be strong enough to warrant closure of next bank. With diversified structure, the credit risks are more evenly spread across banks. When the number of banks is large, it is completely diversified so that no contagion exists.

In Allen and Gale (2000), the standard one policy tools, that can restore first-best in the one bank case, will work. But the timing and implications of central bank intervention will depend crucially on the interbank market structure, as discussed above, connecting banks. Only in the special case of an incomplete network, will policy intervention be necessary. Because the origin of the banking panic transmission is an initial liquidity shock at one bank, it follows that ex-post measures (such as Suspension of Convertibility (SOC)) at that bank, will help. The main point is that the interbank connection creates a direct link between the balance sheet of banks and constitutes the main channel for transmitting a crisis across banks. As long as the crisis is prevented at the crisis-catalyst bank, the balance sheets of all banks will be preserved. Thus, these policy measures do not create an externality of their own, on other banks. All arguments regarding policy measures in the one-bank setup, will apply. Contagion will be prevented (since none of the banks' claims are affected).

The concept of Lender-of-Last-Resort (LOLR) needs elaboration. LOLR is typically carried out when, it is feared that a bank that is experiencing temporary liquidity problem, may potentially become insolvent and the policymaker cannot easily make the distinction between illiquidity and insolvency, due to informational problems. LOLR is also administered when it is feared that an illiquidity problem at a bank, can spread across banks amplifying all along the way, until it becomes degenerate. Since the Allen and Gale (2000) framework deals overwhelmingly with assessing channels that connect banks constitute the main externalities during times of troubles, it is obvious that LOLR, in such models, should be viewed more from (2), rather than (1). By providing emergency funding to banks facing illiquidity problems, LOLR ensures that there is no need for the bank to liquidate its long asset – which prevents the value of claims that other banks hold in it to fall. Thus the spillover effect is thwarted.

It is important to note that agents in the Allen and Gale (2000) setup have complete information about their operating environment. In real world though, the analysis of LOLR, is conducted in an environment in which the central bank has incomplete information about the liquidity and solvency positions of banks. In this case, it will be optimal for the central bank to intervene if doing so entails benefits (in terms of preventing multiple collapse) that outweigh the costs (in terms of taxpayers' money), so that, from a more generalised perspective, it is welfare improving, from society's point, to do so.

Not many papers adopt the same perspective. Rochet and Tirole (1996) argue that, in a multiple bank setting, contagion may be good and no policy intervention whatsoever is needed, because it helps promote peer monitoring among banks and achieves market discipline. They study a system in which ex-post lending may be allowed to mitigate systemic risk, while still preserving the benefits of ex-ante monitoring. If no monitoring is allowed, then bank managers have an incentive to act opportunistically and undertake activities that may not necessarily be in the interest of other stakeholders. To prevent this behaviour which leads to moral hazard, some form of monitoring technology is used.

In the Rochet and Tirole (1996) model, banks face heterogenous liquidity shocks. Those that cannot raise liquidity are forced to stop their projects and go bankrupt. To prevent this, banks with excess liquidity can lend to banks facing liquidity shortage and monitor the borrowing banks, provided the costs of so-doing, are not too high. Under incentive-compatible interbank lending, the performance of the lending bank must be dependent on the performance of the borrowing bank, but not vice versa. Only under this condition, will the lending bank have an incentive to monitor the borrowing bank. This suggests that, sometimes, it may be good to close down a solvent bank with exposures to illiquid bank. It may be good to allow contagious effects resulting from bank failures to spur optimal monitoring. An optimal public policy will present a trade off between the benefits of allowing contagious effects (e.g greater monitoring and market discipline) against the costs of so-doing.

2.3.2 Models with Informational Spillovers

Models with informational spillovers mainly focus on the spread of a crisis from one bank to another, in a setup in which the banks' fundamentals are believed to be correlated. There is no direct link connecting the banks, in the form of contractual arrangements such as interbank market in deposits and loans.

Nonetheless, the underlying fundamentals are perceived to be correlated, in a way that invites correlation in payoffs of depositors of both banks. Hence events at one bank provide information to depositors of other banks and the failure of one bank leads depositors of the other bank to adjust their expectations in such a way that their bank suffers from the same fate as the first bank.

Chen (1999) studies a multiple bank setup in which the existence of demand deposit contracts coupled with informational spillovers, leads to some form of strategic complementarity and hence create conditions for contagious banking crises. Banks basically invest in risky assets, with the returns to risky asset, being positively correlated across banks. In each bank, a fraction of patient depositors observe the return to the risky asset perfectly. In addition, these depositors do not observe their signals at the same time: depositors of a subset of banks move first (i.e take their decision first) and then, depositors in the remaining banks act. Depositors in the latter group are assumed to noisily observe the number of bank failures in the first group of banks. They may run on their own banks, even before observing their signals about their own banks' project realisations.

Chen (1999) goes on to show that, given demand deposit contracts, there exists a critical threshold in the number of failures among the first mover bank. If the actual number exceeds the critical threshold, then all depositors in the remaining banks will run on their banks. The specific features of the contract are also analysed. The optimal deposit contract is influenced by any possibility of bank panic. Bank panics become more likely, the higher the prior probability about the state of the economy being bad and the higher the period 1 (i.e interim period) deposit payment.

Robustness and Policy Implications

Chen highlights an important attribute of models involving contagion from informational spillover effects: that information transparency is important in mitigating the spread of crises. The same can be said about Dasgupta (2004). By increasing the precision of signals and coordinating beliefs on the proper outcome, the 'contagion spread' can be minimised, thereby mitigating the onset of a crisis spread. Archarya and Yorulmazer (2008) reach a similar conclusion. They extend the informational spillover approach by constructing a model of systemic risk involving banks, with informational contagion existing on banks' liabilities side, and bank loan correlations existing on the asset side. The interaction between the two enables them study the ex-post and ex-ante aspects of systemic risk. In their model, the return to bank loans has two components: a systematic component and an idiosyncratic component. Depositors can observe the overall realisation of bank loan returns, but not the actual decomposition.

So, when one bank fails, depositors of the other bank think that signals send bad news about the overall performance of the economy, and use Bayes rule to update their priors. The rate of return on deposits (or borrowing) to staying in the second bank, is adjusted in such a way that it shares a similar fate to the first bank. To mitigate this informational spillover resulting from one bank's events on another bank's borrowing costs, both banks engage in ex-ante herding (i.e endogenously choose correlated portfolios) in order to maximise the possibility of joint survival. The model has policy implications that share similar tenets to those of Chen (1999): as long as a policy instrument succeeds in making the interest rate on deposits (or borrowing) insensitive to bank events, no informational spillover occurs and the ex-post cost of mitigating contagion will be minimised. Informational transparency would, for example, make the distinction clear between the systematic and the idiosyncratic component of bank loan returns. If depositors of the second bank know that the bad performance of the first bank has been due to idiosyncratic poor performance of loans of the first bank and not due to overall bad performance, then they will not be tempted to run on their own bank. Thus, no informational spillover results.

Other approaches in the literature consider the interaction between informational spillover effects and aggregate liquidity position: Aghion, Bolton and

Dewatripont (2000) show how, in the presence of imperfect information about banks' liquidity , a liquidity problem at one solvent individual bank level, may have widespread contagious effects.

If banks are subject to uncertainty in the timing of realisations of their long asset returns, a liquidity shock could lead to a high proportion of cash-strapped banks (banks that are faced with the prospects of delayed returns and high short term deposit withdrawals) relative to cash-abundant banks (banks that are faced with the prospects of immediate returns realisations and low short term deposit withdrawals). If the cash-abundant banks can service the cash-strapped banks through the interbank market, there is no need for public policy intervention. Should the amount required be beyond the reach of cash-abundant banks altogether, then there will be aggregate liquidity shortage, with some cash-strapped banks being rationed (the interbank lending rate is fixed) whereas others are forced to liquidate their long assets. By observing other bank failures, depositors think that this may be due to aggregate liquidity shortage. Fearing the worse about their own bank, they withdraw. The inability of the interbank market to function effectively means that there is a case for public policy intervention. In a similar spirit, Diamond and Rajan (2001) consider how, through an interplay between illiquidity and insolvency, an aggregate liquidity shortage leads to contagion. Their paper is closely related to Aghion, Bolton and Dewatripont (2000), but stresses that banks facing liquidity problems usually try to issue new deposits to bridge the liquidity gap. To do so, they must raise interest on deposits. This reduces the value of bank assets and leads to insolvencies.

Policy implications have similar traits to those of informational spillover models of Chen (1999) and Archarya and Yorulmazer (2008). Increased transparency will enable depositors to distinguish between aggregate liquidity stance and their own bank's liquidity position. As a result, they will be able to make more reasonable judgements about their own bank's position. Injection of liquidity into the system can be carried out, but there are questions that will inevitably come up as to whether the liquidity injection should be applicable to cash-strapped banks only. Aghion, Bolton and Dewatripont (2000) investigate the costs and benefits of having an unregulated banking system. While the absence of public safety nets provides incentives for peer monitoring and eliminates moral hazard among banks, it also fails to block the channel through which aggregate liquidity shocks are channelled throughout the banking system. This brings questions about what the optimal public safety net should be.

How about standard Central Bank policy measures ? An interesting contradiction with the models of contagion based on direct links as above, is that here, the expectations of depositors are explicitly modelled. Thus, the effectiveness of policy measures administered at the bank experiencing the initial shock, will depend crucially on how depositors react to these policy measures. Generally, such measures applied to the initial bank, will create an externality (positive or negative) on other banks. As such, policy measures, by themselves, may create a distortion between privately optimal and socially optimal outcomes and beg in questions as to whether these measures should not be more 'general' (i.e applied to those banks that are considered to be most vulnerable to informational spillover effects, rather than to banks that experience the liquidity shock in the first instance).

2.3.3 Models with Asset Price Changes

Amongst others, Schnabel and Shin (2003) find evidence of high asset price correlation for different assets in Europe, during times of financial distress. The obvious explanation is aggregate liquidity shortage. Cifuentes, Ferrucci and Shin (2005) show that, with a pattern of interconnectedness generated by a rich structure of cross-holdings, coupled with the existence of regulatory solvency constraints, the demand for illiquid assets is less than perfectly elastic, so that asset sales to meet liquidity demands by institutions will largely depress asset

FIGURE 2.6: Models with Multiple Banks

	Ex-ante policy measures	Ex-post policy measures
Interbank Network Connections (through Balance Sheet)	Design of network structure connecting banks matters	(only in incomplete network structure): Policy measures taken at bank experiencing the liquidity shock (same as one-bank setting): No need to take account of spillover effects that policy measures will present to other banks
Informational Spillovers	Increased transparency for more informed judgement	Policy measures taken at bank experiencing the liquidity shock : there is a need to take account of spillover effects that policy measures will present to other banks

prices. Many studies find evidence for an asset price channel, as potential explanation of a spread of a crisis from one bank to another. The main policy implications are illustrated in Figure 2.6.

The determination of asset prices, in equilibrium, will depend on the availability of liquidity in the system . If banks have access to efficient markets for liquidity provision, then there will be no need to liquidate assets, and, asset prices will not be affected. In the event in which illiquid banks are forced to liquidate their assets in order to meet demand for liquidity, the price of such assets may fall – thereby affecting the value of portfolios of all banks in the financial system. We shall refer more explicitly as to why the prices fall during liquidation and what corrective mechanisms may be taken to mitigate asset price changes in the next section.

2.4 Financial Intermediaries and Financial Markets

Banks facing illiquidity problems usually have recourse to financial markets or to the interbank market in order to alleviate their temporary illiquidity problems. It is the purpose of this section to consider what market failures may inhibit the smooth operation of the financial market or the interbank market, thereby preventing banks from getting access to much needed funding, and explore what policy measures may help restore the efficient operations of the markets. Denial of funding in times of trouble may lead to insolvencies, with system-wide implications.

Till now, as far as 'homogeneous banks' are concerned, we have kept financial intermediaries and financial markets as separate from each other. A bank can use financial markets in three main ways:

[**1**] It can use financial markets as a way of insuring against aggregate risks – here, risks are taken to mean uncertainty about the distribution of early withdrawals or uncertainty about the realisation of investment returns in the long technology.

[**2**] It can use financial markets to trade the long asset. The illiquid asset may thus be liquidated in order to meet liquidity demands that cannot be met from the short asset alone.

[**3**] It can use financial markets as a basis to issue claims against the long asset (securitization).

Integrating financial intermediaries and financial markets in a micro based model has important implications for systemic risk and financial fragility. Gale (2004) argues that introducing these markets into models of financial intermediaries, has important implications for the welfare properties of the model: on one hand side, bankruptcy involves no inefficiency ex-post – firesale prices simply represent transfers rather than deadweight losses. On the other hand side, ex-ante risk sharing is optimal if there exists a complete set of Arrow securities for hedging against these aggregate risks.

Banks, so far, have been assumed to liquidate their assets through some exogenous technology, with the price of the asset and the supply of liquidity, being taken as given. This is a rather strong assumption. By trading their assets, the price at which the asset is traded, is no longer exogenous, but rather, set by equilibrium forces of demand and supply in the bond market. This provides important insights into analysis of asset price volatility and endogenous liquidity provision. In the presence of market failures such as incomplete markets for hedging against aggregate uncertainty or incomplete trading opportunities, a bank's interaction with the financial market, may lead to excess price volatility for the asset, in such a way that this jeopardises the ability of the bank to meet liquidity demands and fulfil contractual obligations. This provides important insights into the phenomenon of financial fragility i.e a situation in which small shocks can have wide impact on the financial system. The weakest link in this interplay between banks and financial markets is often the crucial role of liquidity in the determination of asset prices. In the presence of incomplete markets and aggregate uncertainty, financial intermediaries are forced to sell assets in order to obtain liquidity. But since holding liquidity involves an opportunity cost, the suppliers of liquidity can only recoup this cost by buying assets at resale prices in some states of the world – this private provision of liquidity by financial markets is always inadequate to ensure complete asset price stability – which therefore reflects failure of the market mechanism to allocate resources efficiently to the banking system and calls forth, the need for public policy intervention.

'Heterogenous banks' may engage in the interbank market, through ex-post interbank lending or ex-ante cross holding of deposits, as crisis prevention measure against liquidity shocks. The interbank market was covered in the previous section. However, we were then more concerned with the role of interbank market connections as representing possible externalities propagating a crisis from one bank to another. In this section, we shall not be concerned with how interbank market failures may spread a crisis across banks but rather, with what the different possible forms of interbank market failures are, and how to eliminate them. Goodfriend and King (1998) argue that if the interbank market is efficient, then any solvent but illiquid bank will always get the funding it needs at times of difficulty. In that case, there would be no need for the central bank to intervene and its activity will be limited to monetary stability only.

In case of inefficiency though, a solvent bank facing temporary illiquidity problems may turn out to be insolvent if it does not receive adequate funding. Public policy interventions, such as lender-of-last-resort, would be highly desirable. Even if government intervention is justified in the presence of market failures, there remains key questions about the desirability of such policies and the particular forms they may take.

2.4.1 Homogenous Banks and Financial Markets

Donaldson (1992) develops a model in which the monopoly power of some banks may lead to significant underprovision of liquidity. Banks facing a temporary illiquidity problem, sell securities or claims on their long illiquid assets. There are two sides of the market: institutions that demand liquidity (i.e cash-strapped banks) and suppliers of liquidity to the banks (i.e reserve agents). Banks issue these claims to reserve agents, with the price of these claims being determined by competition among reserve agents. When the demand for liquidity is low or no reserve agents enjoy market power, then the securities will trade at normal or fair prices. Conversely, if the demand for liquidity is high or there is some form of monopoly power among reserve agents, these securities will trade at prices below their fair value. If the reserve agents are interpreted as banks that have excess liquidity, then their monopoly power depends on: their proportion relative to the total number of banks and the distribution of excess liquidity is more favourably biased towards some banks only, so that the other cash rich banks have resources that are not enough to meet total liquidity demand in the economy.

Suppose there is some exogenous productivity shock that affects a fraction of banks only: this shock causes the rate of return on illiquid assets to fall below the level promised to patient depositors. These depositors will run on the bank. The latter will be forced to issue securities on its long asset in order to meet any excess demands for withdrawals.

If the demand for liquidity is strong enough that it almost inevitably affects price of securities negatively, this makes it costly for all banks to obtain liquidity. Thus, technology shocks affecting liquidity position of some banks only have implications for asset prices of all banks, and, correspondingly may affect the solvency of other banks as well. Thus, financial contagion arises.

Allen and Gale (1998) extend the Diamond and Dybvig (1983) setup by considering complete illiquidity of the long asset technology and by making the return to the long technology stochastic, dependent on economic factors. By doing with the assumption of complete asset illiquidity, any form of panic-based bank runs, is eliminated. It also implements the optimal risk-sharing allocation, which is achieved by making consumption in the interim period (i.e period 1) dependent on the stochastic return of the long technology. From that perspective, bank runs can be seen to play an equilibrating role: Since there will always be something left for patient depositors to consume in period 2, early withdrawals by some patient depositors positively affects the payoff to period 2 withdrawals and lowers the return to period 1 withdrawals. Even though bank runs occur with positive probability, they are only partial i.e they involve only a fraction of late depositors withdrawing early (unlike Diamond-Dybvig (1983), which involves all late depositors withdrawing early). In the model, bank contracts together with the occurrence of bank runs, can be seen to provide the right contingencies that allow the first best allocation to occur.

Allen and Gale (1998) then relax the assumption of complete illiquidity of the long asset by allowing for incomplete trading opportunities: the bank is allowed to trade securities through the issue of claims on the bank's long assets. This allows the endogenous determination of the long asset price and endogenous supply of liquidity to the bank. The deposit contract promises to pay a certain fixed amount to depositors wishing to withdraw early. If the amount provided does not suffice, the bank is forced to sell its long asset, so that those depositors who withdraw early, share the liquidation value of the bank. If the price at which the asset is trading in the financial market, is equal to its long term value, then, even with bank runs, the allocation is optimal. This price is, however, shown to be below its long term value, suggesting that the market underprovides liquidity when the bank is facing a run. There is a resulting redistribution of resources from depositors to potential buyers of assets or speculators. While still satisfying the objectives of liquidity provision to the bank (though underprovided), financial markets break the possible advantages associated with bank runs as possible equilibrating mechanism because the optimal risk-sharing allocation is not achieved. On the other hand, buyers of assets benefit greatly because they are able to buy the long asset for a price which is below its long term value.

Robustness and Policy Implications

For financial markets, one of the main points we focused on, was the fall in asset prices that results, following a desperate attempt by the bank to meet its contractual liquidity obligations. This asset price fall is intimately related to the supply of liquidity. In the case of incomplete markets, this supply may not be enough to ensure full asset price stability. In models involving monopoly power as principal source of market failure and liquidity underprovision, market structural features were also an important contributor. What is needed is a mechanism to prevent the price from falling when banks attempt to sell assets.

Public policy intervention, in the form of central bank finance, could prove helpful here. If the Central Bank provides a repurchase agreement (i.e one in which it buys the illiquid asset at its face price from the bank at the time the bank needs liquidity, and, sell it back to the bank at the same price later), could help. By preventing the asset price from falling, the Central Bank successfully achieves its twin goals of liquidity provision during times of financial distress and prevention of systemic risk.

In some cases, liquidity provision is seriously impeded by coordination failure problems. For example, it may be costly for cash-abundant banks to provide funding to cash-strapped banks. There may be incentives for each cash-abundant bank to free ride in provision of liquidity whenever the amount of liquidity demanded is beyond the reach of each individual member but within the reach of a fraction of cash-abundant banks. In all cases, as remniscent of models of coordination failure, there are multiple equilibria – with a 'good' equilibrium depicting adequate liquidity provision and a 'bad' equilibrium, depicting inadequate liquidity provision. This provides a clear case for a central bank to intervene so as to reorganise banks and coordinate beliefs on the right outcome. In Donaldson (1992), the monopoly power is higher the more concentrated the supply of liquidity is among a few banks only, and, within this category of cash-abundant banks, the more biased the distribution of liquidity is among a few banks. Banking regulation, in the form of a well articulated competition policy in the banking industry, may be helpful in eliminating this threat of monopoly abuse, although Donaldson (1992) does not make clear, what specific form this competition policy may take . In cases in which the amount desired falls beyond the means of any individual bank, intervention in the form of lender-of-last resort, may be desirable.

Allen and Gale (2004) build on their previous studies (Allen and Gale (1998), (2000)) to provide sufficient conditions for ensuring efficiency in markets, through properties similar to those related to the fundamental theorems of welfare economics. Their argument can be summarised in Figure 2.7 (please turn over). In

FIGURE 2.7: Incentive Efficiency vs Constrained Efficiency

	Complete Markets (No justification for Public Policy intervention + No market failure)	**Incomplete Markets** (Justification for Public Policy intervention + Existence of market failure)
Complete Contracts	Incentive-Efficiency (First-Best Solution)	Inefficiency
Incomplete Contracts	Constrained-Efficiency (Financial crises can be seen to provide the right contingencies that bring efficiency)	Inefficiency

a setup with financial intermediaries and financial markets, what justifies policy intervention, is simply whether markets for aggregate risks are complete or not. Rationalising the case for financial intermediaries based on limited participation of agents in markets for contingent commodities, they point out that allocation is *'incentive efficient'* if financial intermediaries issue complete contracts. In the case in which market for risk is complete but banks are restricted to using non-contingent deposit contracts, default introduces a degree of contingency that may be desirable from the point of view of optimal risk sharing. Far from being best avoided, financial crises are desirable in order to achieve *'constrained efficiency'* , but this does not imply a market failure. This means that there is no justification for regulation by public authorities. In order for regulation to be justified, it is imperative that markets are incomplete. As in standard theories of government regulation, it is first necessary to identify a market failure in order to analyse intervention.

This approach was used by Gale (2004), in considering the optimal bank capital structure. Bank capital usually serves two purposes: it acts as a buffer against unexpected declines in bank asset values and it acts as a mechanism that discourages excess risk-taking behaviour from the part of bank managers. In the presence of deposit insurance, depositors have no incentive to monitor bank managers and the latter have an incentive to pursue a risk-reward strategy ('gamble for resurrection') in order to maximise the option value of the deposit insurance. Bank capital is required in order to check this possibility of moral hazard. Whether deposit insurance is a sufficient condition for justifying regulation of bank capital or not, is highly debatable. Hellman, Murdock and Stiglitz (2000) develop a model that allows for the effect of higher charter value and capital adequacy requirements on risk-taking incentives. Control of interest rates, together with capital adequacy requirements, are necessary to achieve a Pareto-efficient allocation of resources.These interest rate controls increase charter value and provide extra instrument for controlling risk taking. A Pareto improvement is possible even in the absence of deposit insurance.This requires that the need to justify bank capital regulation, must ultimately be down to market failures. If banks can fully internalise the full costs and benefits of capital requirements, then the privately optimal level of capital will coincide with the socially optimal level – then, there would be no need for policy intervention. For there to be a role for public policy regulation of bank capital, it must be shown that the capital requirement level chosen at one bank level imposes welfare-relevant pecuniary externalities on other banks.

In an Arrow-Debreu economy with complete markets, capital structure is irrelevant and the standard Modigliani-Miller theorem result holds. The privately optimal level of capital coincides with the socially optimal level and there is no justification for regulation. Complete markets act as a perfect substitute for capital. In the case in which markets are no longer complete, capital structure becomes determinate but the privately optimal level of capital still coincides with the socially optimal level. So, the case for public regulation of capital is again absent. In order to make a case for regulation, heterogeneity must be introduced among financial institutions, for example, banks facing different regional liquidity shocks. Efficiency would require cross-sectional (interbank) risk sharing, in which banks basically cross-insure each other against regional liquidity shocks.

In the absence of complete markets, this efficient cross insurance cannot be attained. Thus, there is a case for public policy intervention. Irwin, Saporta and Tanaka (2005) extend the Allen and Gale (2004) setup, by considering a model of the financial system with heterogeneous banks and investment fund, within which financial crises can arise endogenously. Banks are subject to idiosyncratic and aggregate risks only whereas investment funds are subject to aggregate risks only. Banks and investment funds interact through financial markets but the authors assume that financial markets for trading assets are incomplete – which prevent the financial intermediaries from offering state-contingent contracts that can replicate complete markets outcome. In the paper, due to different risk appetite for investment fund customers and bank customers, investment funds can be seen as mechanisms that increase the welfare of banks by improving the risk-opportunities for the banks' customers. For high levels of risk aversion, banks face excessive risks but investment funds face too little risks. For low levels of risk aversion, the risk profiles are inverted across banks and investment funds.

The consumption allocation does not match the (Pareto optimum) consumption allocation under a complete market – thereby leaving scope for welfare improving policies. The focus of the paper is on optimal policies that can be used to achieve the Pareto optimum consumption profile and to mitigate financial instability. Lump sum taxes and transfers between financial intermediaries can replicate the complete markets outcome for reasonable degrees of risk aversion, if they are contingent on the aggregate liquidity.

Liquidity requirements, however, cannot achieve Pareto-efficient consumption allocation . The intuition is steadfast: under reasonable ranges for risk aversion coefficient, banks face excess consumption risks whereas investment funds face too little risks. Increasing banks' holdings of liquid assets will reduce price volatility and expose bank customers to lower consumption risk, at the expense of decreasing expected utility of investment funds customers that would prefer more rather than less consumption risk. Thus, liquidity requirements cannot achieve the first-best outcome. The paper goes on to show how, regulation of one institution's liquidity position can lead to an inferior welfare outcome whereas regulation of both institutions' liquidity position can lead to a higher population-weighted utility.

Pagratis (2005) considers the interaction between liquidity requirements and LOLR, in a setup in which the central bank performs both, the LOLR activity as well as designing appropriate regulatory policy. Prudential liquidity regulation is considered to be a quid pro quo for emergency lending assistance by the central bank where prudential liquidity is considered to be an implicit insurance to banks in return for LOLR insurance. In the presence of funding constraints and possibility of information-based bank runs, the conditions under which liquidity requirements would be socially desirable, are examined. It follows that liquidity requirements serve as first line of defence against banks' liquidity problems that allow the central bank to maintain zero expected cost of LOLR intervention, while counteracting excessive risk-taking. Thus, the more debt-constrained the banking sector is, the higher profit opportunities are and the less stable the deposit base is, the more prudential liquidity regulation is regarded as socially desirable.

2.4.2 Heterogenous Banks and the Interbank Market

So far, we have been focusing our analysis, in this section, at the case in which one bank dealt with a financial market and, how that interaction may lead to financial fragility. The essence of the analysis would stay if we focused on homogeneous banks. In the presence of heterogeneous banks though, provision must be made to allow for the presence of the interbank market as a means of liquidity provision and liquidity shock insurance. As shown in the previous section, one possible way of interpreting the heterogeneity of banks, would be to allow for the presence of regional shocks that are negatively correlated across banks.

The focus of this subsection will be on the market imperfections that may impinge on the ability of the interbank market to channel resources efficiently among banks. If there is no aggregate uncertainty and no market imperfections plaguing the interbank market, there is nothing that prevents an efficient allocation, as Goodfriend and King (1998) argued. Should any of these imperfections arise, the interbank market no longer provides perfect insurance and an illiquidity problem may turn into insolvency, with system-wide implications.

One source of market imperfection is informational asymmetry – banks in the interbank market may not lend to cash-strapped banks if they do not perfectly observe the composition of the borrowing banks' balance sheet or if the amount to be borrowed is too large compared to resources of the lending banks. This arises because this lack of observation makes it difficult to distinguish between a case of insolvency and a case of illiquidity. As a result, interbank market may be channelling loans to cash-strapped banks, against the promise of the banks' assets. But the banks may be willing to liquidate all bad loans ('non performing') from their portfolio, so as to keep the good ('performing') ones. The amount lent by the interbank market may not be sufficient to generate their value in the interbank market.

Bhattacharya and Gale (1987) develop a model in which informational asymmetry exists among banks, as regards each bank's asset composition and the size of liquidity shock that each bank faces. They show that, in the presence of such market imperfections, each bank will have an incentive to free-ride on the holding of liquid assets, since holding liquid assets is costly. The interbank market leads to underprovision of liquidity due to free-rider problems. They allow for interbank lending, in the absence of aggregate risk. The existence of the interbank market, is to allow banks to borrow and lend to each other.

A bank's liquidity and investment needs are private information, observable to the bank alone. In equilibrium, both type of banks hold the same amount of reserves – the only uncertainty is about the need for liquidity to meet early withdrawals. Either type of bank may not truthfully reveal its type in the interbank market. If interbank rate is lower than the rate of return on illiquid asset, the optimal deviation is for both types of banks to borrow from the interbank market. Since holding liquid assets is costly and, under model parameters, the return on interbank loan is lower than that of long term investment, there will be liquidity shortages at the aggregate level, even in the presence of the interbank market. Banks will free-ride on each other for liquidity and underinvest in liquid assets.

Bhattacharya and Fulghieri (1994) extend the Bhattacharya and Gale (1987) model, by allowing for uncertainty in the timing of short asset payoffs. While the long asset pays off only in period 2, the short asset may pay off in period 1 or 2. Thus, with some positive probability, it may not pay off in period 1 – in which case, banks holding it will face a liquidity shortage. The incentive-constrained second best solution requires that the return on interbank lending is higher than the return on the long term asset. Thus, banks that have excess liquidity, will always be compensated for giving away that excess liquidity to cash strapped banks, through high interest rates. As a result, banks that have excess liquidity are profitable, despite the fact that holding liquid assets is costly. In equilibrium, banks may over or under-invest in the liquid asset.

Alger (1999) allows a multiple-bank setting, with the presence of credit risks, as market imperfections, in the interbank market for lending. The model is very identical to the Diamond-Dybvig (1983) framework, but with the added feature that the returns to the long technology is stochastic and the illiquid asset returns are correlated across banks. In addition, banks are subject to a probability of being solvent or insolvent, with this possibility of insolvency being independent of the liquidity shock realisation. The properties of interbank lending are analysed when banks have first best level of reserves, in the presence of credit risks. Following the realisation of liquidity and solvency shocks, there will be two types of banks: liquid and illiquid banks. A liquid bank that is insolvent will always lend to an illiquid bank, in a desperate attempt to maximise the option value associated with its assets. A solvent and liquid bank will only lend if credit risk is low and the probability that it gets paid back, is high. Thus, in the presence of a market imperfection in the form of a credit risk, the interbank market may fail to allocate resources efficiently to cash-strapped banks.

Robustness and Policy Implications

In this section, we have focused on the inability of the interbank market to provide funding efficiently due to the existence of financial frictions or market imperfections. The inefficiency that result may be strong enough to force otherwise solvent but illiquid banks into insolvency, with system-wide consequences. The type of contracts that exist in each model are pre-specified: in Bhattacharya and Gale (1987), banks write contracts beforehand i.e prior to observing the liquidity shock. In Alger (1999), banks write the contracts after the realisation of the liquidity shock and turn to the lending markets only ex-post.

In the interbank market for lending, the first best solution is reached when the optimal level of liquid reserves can be achieved. If this requirement can be attained ex-ante, then any form of trading in the interbank market can maintain it ex-post. In the case of non enforcement of this optimal level of liquid reserves, the second best is reached. In that case, some form of noisy monitoring, would constitute some form of Pareto improvement. Bhattacharya and Gale (1987) thus offer a rationale for official monitoring of liquid asset holdings by banks, suggesting that liquidity shortages may arise as a result of banks' incentives to free ride on interbank liquidity, rather than holding liquid assets themselves. In the presence of credit risks in the interbank market for liquidity provision, the first best level of liquid reserves, no longer guarantees efficiency. As seen in Alger (1999), banks may be unwilling to lend if credit risks are deemed to be too high. Possible policy solutions include introducing mechanisms that allow trade to take place in the interbank market, for example, through central bank credit lines.

The case for LOLR should also be put into perspective. As aforementioned, LOLR serves two purposes: [**1**] prevention of the contagious transmission of an illiquidity problem across banks and [**2**] prevention of illiquidity problem at a crisis-catalyst bank from turning into a bankruptcy one. Regarding the role of LOLR in dealing with banking crises, Goodfriend and King (1988) argue that solvent banks could perfectly insure against the possibility of bank runs via a sophisticated interbank market, suggesting that Central Banks should focus on maintaining a sufficient amount of liquidity in the system, rather than providing the LOLR facility. However, as we have seen, various forms of market imperfections prevent the interbank market from operating efficiently and may turn an illiquidity problem into an insolvency one.

The argument by Donaldson(1992), that cash-abundant banks may abuse their monopoly power and charge above competitive rates, suggests that there is a clear cut case for LOLR. Goodhart and Huang (2005) argue that, if the amount of funding needed is beyond the reach of the interbank market or if the interbank market is plagued by coordination failure, it will be unable to provide liquidity to cash strapped banks. They also argue that the interbank market may not be able to provide insurance against liquidity shocks if these shocks happen to be systemic, affecting the whole banking system. To quote:

"......(some economists) believe that providing LOLR to individual banks, rather than to the market as a whole (via open market operations (OMO)), is

fundamentally misguided.....such economists believe that Central Banks should not lend to individual banks, e.g., through a discount window; the market is as well or better informed than the Central Bank about the relative solvency of a bank short of liquidity. Given an aggregate sufficiency of high-powered money, illiquid (but solvent) banks will be able to borrow in the interbank market, whereas potentially insolvent banks will be driven out of the system..... direct intervention may divert the Central Bank from achieving its primary goal of controlling the monetary aggregates so as to achieve price stability....

*......(the first counterargument to this point) is the potential for "**market failure**". For example, when the Bank of New York computer malfunctioned in 1985 and would not accept incoming payments for bond market dealings, the resultant illiquidity position soon ballooned to a point where no one counterparty bank could take on the risk of making a sufficiently large loan. It would have required a coordinated syndicate, but such syndicates take time to organize, and time was scarce. An even more dramatic example is given by the recent events of September 11, 2001. The functioning of many markets had been severely disrupted. In this crisis, the Federal Reserve System hugely expanded its discount window lending to many individual banks ..... Most Central Banks would also argue that their supervisory role – or their ready access to supervisory information – should give them additional information, not available in the market. Moreover, as in the case of the Bank of New York, when there is any large-scale need to redirect reserves, there must be a "**coordination problem**". No one commercial-counterparty can single-handedly assume the credit risk, and there is no incentive for a single commercial bank to take on the time, effort and cost of coordinating the exercise of sorting out the problem......"* (Goodhart and Huang[5] (2005))

According to Goodhart and Huang (2005), coordination failure may thus be defined as "*a condition where a bank, (or, as in the case of 9/11, a set*

[5] Journal of Banking and Finance, Vol 29, Issue 5, pp 1059-1082 (pp 2-4)

of banks), is solvent, but illiquid, but the market cannot resolve this difficulty, which would be temporary if resolved quickly" (pp 4). This may be because of aggregate correlated shocks in the system or credit counterparty limits that prevent any single banking institution from undertaking the necessary lending. The latter requires co-ordinated lending from a syndicate of potential lenders. The syndicate may likewise be unwilling to undertake the transaction costs of acting as co-ordinator due to system-wide under funding or because markets themselves are shut, or malfunctioning as on 9/11 or for a variety of other potential reasons.

Rochet and Vives (2004) argue that, under certain circumstances, LOLR may be welfare improving. It prevents inefficient liquidation of a bank's assets and improve welfare if the Central Bank has perfect information about bank's fundamentals (i.e can distinguish between a liquid and an illiquid bank). In most cases, imperfect information may mean that public authorities will be confronted with a situation in which they do not observe the solvency of banks they are trying to save through emergency funding. In these instances, they may face the dilemma open to all policymakers in the face of imperfect information: that of either providing funding to illiquid banks that are actually insolvent or that of refusing funding to illiquid banks that are actually solvent. In most instances, in the face of imperfect information, policymakers need to weight the benefits of providing funding (in terms of preventing illiquidity from turning into bankruptcy or preventing the spread of a crisis from bank to bank) against the costs of so-doing (in terms of bailing out insolvent banks, moral hazard costs and absence of peer monitoring), and come up with an optimal plan. Ostensibly, this may mean that the optimal plan varies from case to case.

Repullo (2003) also provides conditions under which a LOLR would be welfare improving, by discussing the effect of LOLR activity on holdings of liquid assets by banks. Due to high costs involved in holding liquid assets, LOLR may prompt banks to lower their holdings of liquid assets, thereby leading to more efficient outcomes. Naqvi (2007) shows that, if the supervisory process is subject to noise, then the ex-post gains in efficiency, resulting from holding a lower stock of liquid assets, may be outweighed by the ex-ante inefficiencies induced by moral hazard, which is conducive to lower rates in the economy.

2.5 Macroeconomic Issues

2.5.1 Financial Accelerator Models

The recent credit crunch crisis of 2007-2008 has highlighted the prominent role of financial intermediaries in affecting the real output of the economy. At the time of writing up this thesis, macroeconomists around the globe, were pondering about the best ways to accommodate the microfoundations of financial intermediaries within the conventional macroeconomic paradigm . Indeed, the pivotal importance of banks in the financial crisis of 2007-2008, has been succintly described by Adrian and Shin (2008) as follows[6]:

"*....Financial intermediaries have been at the centre of the credit market disruptions that began in year 2007. They have borne a large share of the losses including securitized subprime mortgages, even though securitization was intended to parcel out and disperse credit risk to those investors who are better able to absorb the losses. The capacity to lend has suffered as intermediaries have attempted to curtail on their exposure to a level that can be more comfortably supported by their capital. The credit crisis has dampened real activities such as housing, and has the potential to induce further declines. The events of the last twelve months have posed challenges for monetary policy and have given renewed impetus about the interconnections between financial stability and monetary policy.*

[6] "Financial Intermediaries, Financial Stability and Monetary Policy" , by Tobias Adrian and Hyun Sond Shin, Proceedings of the 2008 Federal Reserve Bank of Kansas City Symposium at Jackson Hole, August 2008.

The current credit crisis has the distinction of being the first post-securitization crisis in which the banking and capital market have been closely linked. Historically, banks have always reacted to changes in the external environment expanding lending when the economic environment is benign. However, the increased importance of intermediaries that mark balance sheets to market both sharpens and synchronises the responses, giving more impetus to the feedback effects on the real economy. The potential for adverse real effects are especially strong when banks respond to credit losses or the onset of more turbulent conditions by cutting their exposures, reducing lending, and charging higher risk premiums. Prudent risk management dictates such actions, and the script is well rehearsed...." (pp 1)

While new research is currently under way to try to juxtapose models of banks and financial intermediaries within macroeconomic frameworks, the current literature focuses on Financial Accelerator models. Financial Accelerator models deal with the relationship between a financial system and the real economy. Unlike models we have seen so far in this chapter, most models under the realm of financial accelerator, abstract from financial intermediation (i.e do not subject the analytics of the Savings-Investment nexus as part of the model). Rather, the focus is on how, in the presence of frictions (in the form of informational asymmetries or limited commitment), financial systems propagate shocks to the real economy and amplify real business cycles. The result is excess volatility and larger swings in business cycles, relative to the situation that would prevail with no frictions. Most financial accelerator models focus on the health of debtors' balance sheets or debtors' net worth, as the main vehicle through which informational asymmetries propagate a shock to the real economy.

These financial accelerator models are taxonomised as thus:

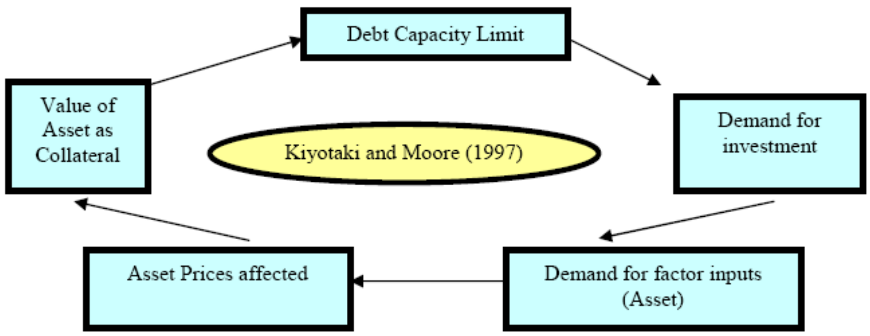
DEBT DEFLATION THEORY The debt-deflation theory was advocated by Irving Fisher in 1930s in the wake of the Great Depression. It highlights the importance of (fixed) nominal debt as the main propagating mechanism of large and persistent swings in business cycles. An unexpected deflation would cause an arbitrary redistribution of income from those who have borrowed money in fixed nominal terms to those who have lent money because the amount owed in real terms is higher. Debtors have higher marginal propensity to consume than creditors. Thus, the decrease in income that results for debtors exceeds the increase in income available to creditors. The decline in net worth of borrowers lead them to cut back on current spending and all future commitments, sending the economy down further. At an aggregate level, the economy is worse off with real output declining.

BERNANKE AND GERTLER MODEL (1989, 1990)[7] This model considers optimal financial contracts in the presence of moral hazard. There is information asymmetry in the form of agency costs that lenders have to pay in order to monitor borrowers accurately. Because it is costly to align the interests of lenders and borrowers, lenders demand a higher share of the returns from their investment projects, relative to the case when there is no informational asymmetry. Thus, external finance is costly relative to any form of internal finance. The higher internal finance, the lesser the extent to which external finance is needed and the lower is the external finance premium. This negative relationship, between internal finance and the external premium (cost of investment), creates some form of mechanism that amplifies business cycles when there is some initial shock. For instance, assume that there is a negative technological shock that reduces the current and future cash flows of firms . This induces a greater need for external financing while raising the firm's external funds premium, and consequently, the costs of new investments. Reduction in investment will lower economic activity and future cash flows, amplifying and propagating through time, the effects of the initial technological shock.

KIYOTAKI AND MOORE MODEL (1997) (Refer to Figure 2.8 on next page

[7] In the bibliography section, I have included this reference as Bernanke and Gertler (2005). Both papers were mentioned in the 2005 reference.

FIGURE 2.8 : The vicious circle in Kiyotaki and Moore (1997)



for illustration). In this model, financial assets act as collateral and also, as inputs used in the production process. This twinned role of financial assets determines the debt limit of borrowers (i.e net worth) and the interaction between these two roles, creates an implicit asset-price channel. Lenders demand borrowers to post collateral in order to prevent them from defaulting strategically. The value of assets as collateral determines the maximum amount that borrowers can borrow. This debt limit will, in turn, determine the amount of investment that cash-constrained firms must undertake and, by correspondence, the demands for factors of production. Since assets also act as inputs, their prices will be affected. This affects debt capacity and the vicious circle process goes on.

There are three facts about financial accelerator models:

[**1**] The nature of debtors' balance sheet lies at the heart of the model. In the debt-deflation theory, fixed nominal debt determined borrowers' net worth. In Bernanke and Gertler (1989, 1990), it is the external finance premium. In Kiyotaki and Moore (1997), it is the value of collateral.

[**2**] In all cases, the firm undertaking the investment project is cash-constrained. Thus, the need for external finance arises naturally given that internal finance alone would not suffice to fund investment projects.

[3] Business cycles have an asymmetric nature in that they tend to be more pronounced in downturns than in upturns. Crucially, the stronger the need to rely on external funds, the stronger the financial accelerator. During downturns, an increasing number of firms become cash-strapped because of the direct impact that downturns may have on their liquidity positions. The need for external finance is thus strong during economic slowdowns. During upturns, the external premium decreases and the firm's debt capacity increases as the firm's balance sheet improves. Firms rely less on external funds in economic recoveries. The potency of the financial accelerator thus varies with the business cycle – being fundamentally strong during recessions and weak during recoveries / booms. Interestingly, this means that downward swings are larger and exhibit more persistence than upward swings. This asymmetric nature of swings retains a powerful implication for the appropriate shape and design of monetary policy. In those economies in which firms are cash-constrained, the Central Bank needs to be more aggressive at relaxing monetary policy during downturns than at tightening monetary policy during upturns.

2.5.2 Banking (Credit) Channel of Monetary Policy

The previous section dealt with how asymmetric information and costly enforcement of contracts create agency problems in financial markets. As aforementioned, an external finance premium, which is a wedge between the costs of funds raised externally (by issuing debt or equity) and the opportunity cost of funds raised internally (by retaining earnings), has an important role in economic activities. The size of the external premium reflects the degree of imperfections in credit markets that drive a wedge between the expected return received by lenders and the costs faced by borrowers.

It is important to note that, in addition to its effect on interest rates, monetary policy will also affect the external premium in a complementary fashion.

Thus, the direct effect of monetary policy on interest rates, will be amplified by changes in the external premium. This supplementary effect helps explain the potency of monetary policy effects on real output. In particular, two mechanisms have been delineated as linkages between monetary policy and the external premium: the balance sheet channel and the bank lending channel.

BALANCE SHEET CHANNEL This channel has its roots in the basic mechanism underpinning the Bernanke and Gertler model (1989), (1990) outlined earlier. A more recent contribution is that of Adrian and Shin (2008). In Bernanke and Gertler (1989), (1990), a borrower's net worth is inversely related to the external finance premium. Thus, monetary policy will affect the external premium, through its effects on borrowers' net worth. Through this mechanism, the quality of debtors' balance sheet will affect their terms of credit. As a result, their investment and spending decisions will be affected.

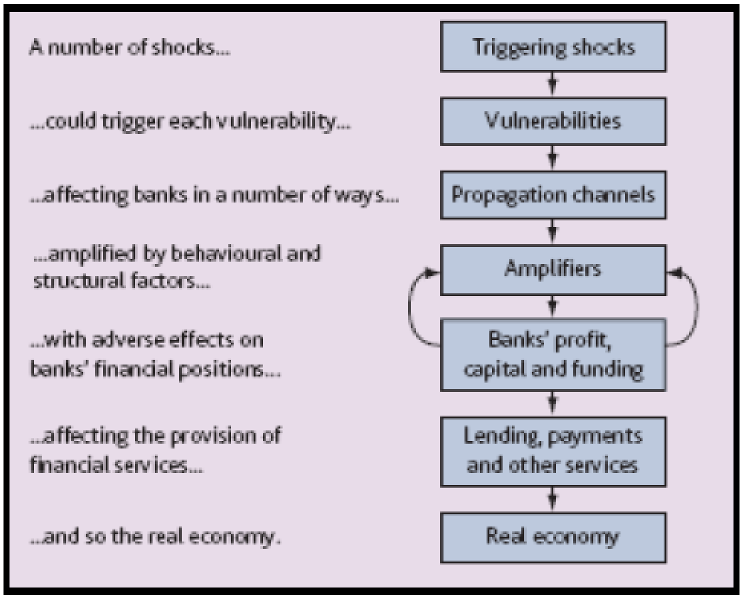
Shifts in policy affect the financial health of borrowers in several ways. Tightening monetary policy by raising interest rates will directly reduce the net cash flows of borrowers and dent their investment spending commitments. These high interest rates are associated with declining asset prices, which may affect borrowers' collateral value and hamper borrowers' credit limits – with real effects on output if borrowers have to cut back on future investment projects. Lesser collateral also affects lenders since their ability to give loans will be restricted. There will be adverse selection problems in the lending market with the increase in market interest rates due to monetary policy tightening – in that, only poor quality borrowers will be willing to borrow at higher rates. Lower net worth and lesser collateral will also encourage moral hazard from borrowers because they will have a greater incentive to engage in risky investment projects. Since taking on riskier investments makes it more likely that lenders will not be paid back in probabilistic terms, a reduction in the firm's net worth will lead to a decrease in lending and subsequently, in investment spending.

More recently, Adrian and Shin (2008) show how the balance sheet of market-based financial institutions, may provide the key transmission mechanism for monetary policy through the capital market. They show that monetary policy that effectively anticipates future deleveraging processes, has a role to play to prevent the decline in economic activity that accompanies financial instability that surrounds deleveraging. The short-term interest rate is an important determinant of the cost of leveraging and interracts with the leverage constraints of financial intermediaries. It may prove crucial in determining the size of the balance sheet of a market-based financial intermediary. High balance sheet growth tends to be followed by low interest rate and slow growth in balance sheet tends to be followed by high interest rate. Adrian and Shin (2008) argue that during episodes of financial stability, the short-term interest rate tends to accentuate fluctuations in the size of balance sheets. Thus, this provides a theoretical rationale for the interconnections between the financial stability role of a Central Bank and monetary policy.

BANK LENDING CHANNEL The bank lending channel works on the asset side of banks and begins with the premise that monetary policy shifts affect the external finance premium through shifts in the supply of bank loans. Bernanke and Blinder (1992) find that, in addition to the traditional effect on interest rates which works through bank deposits, the transmission of monetary policy works through bank loans as well. This view recognises the important role that banks play in channelling funds to small and dispersed borrowers who often lack access to alternative sources of finance from capital markets. This speciality of banks to small borrowers give them a comparative advantage in deriving economies of scope between their borrowing and lending businesses . If the supply of loans is disrupted, bank dependent borrowers may be shut off from credit. Thus, decreasing the supply of loans is likely to increase the external premium and reduce real economic activity. Figures 2.9 and 2.10 (please turn over for illustration) use illustrations from the Bank of England report[8] to depict how shocks affect the banking system of the UK economy and the real economy.

[8] Bank of England (BoE) Financial Stability Report, April 2008, Issue 23, pp 50-51.

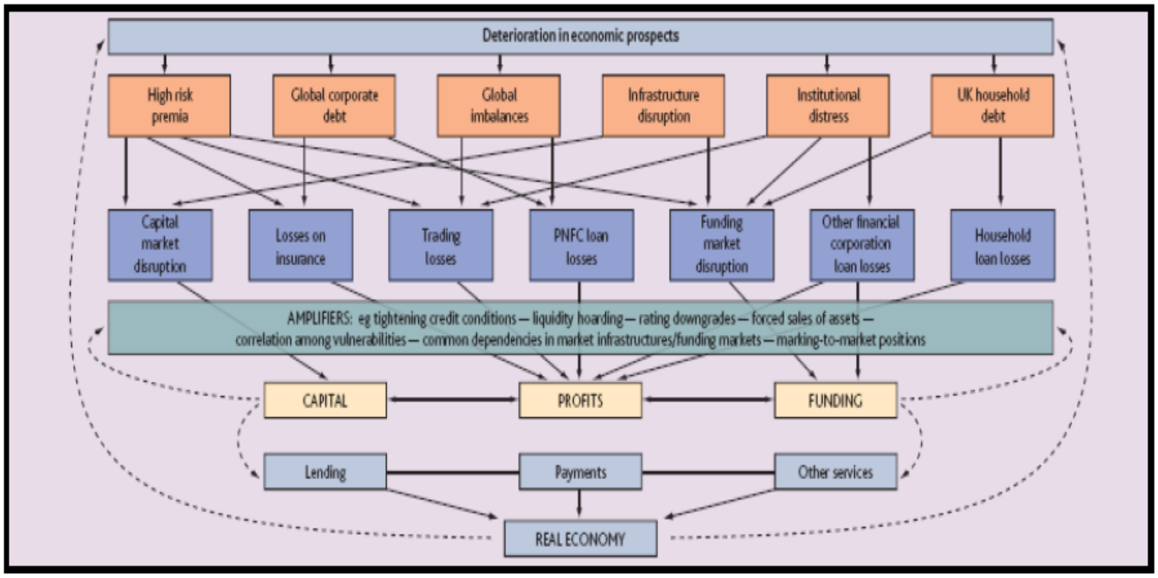
FIGURE 2.9: Bank of England Stylized Transmission Map (Financial Accelerator **(i)**)



Several conditions must hold if there is to be a distinct bank lending channel. First, bank loans and any alternative source of funding (e.g bonds) must be imperfect substitutes among bank assets and for business capital. This assumption creates a distinct role for bank loans and suggests that they are qualitatively different from bonds; second, there exists cash-constrained borrowers who are too small to borrow in the capital markets and who thus rely extensively on bank loans for finance; third, the Central Bank is assumed to be able to influence banks' ability to lend through appropriate monetary policy; Fourth, there are imperfect price adjustments in order to allow monetary policy to have real effects on output.

The credit view is important for several reasons: it highlights the fact that monetary policy can affect real output without much variation in market interest rates. Since there is a well-determined effect on banks' assets, it offers a

FIGURE 2.10: Bank of England Stylized Transmission Map (Financial Accelerator **(ii)**)



fresh and innovative insight into how improvement in banking system can affect the efficiency and effectiveness of the monetary transmission mechanism. Furthermore, the credit channel can explain the distributional effects of monetary policy on lenders and borrowers, while the alternative sources of transmission mechanism (e.g exchange rate channel, asset price channel, interest rate channel etc) cannot.

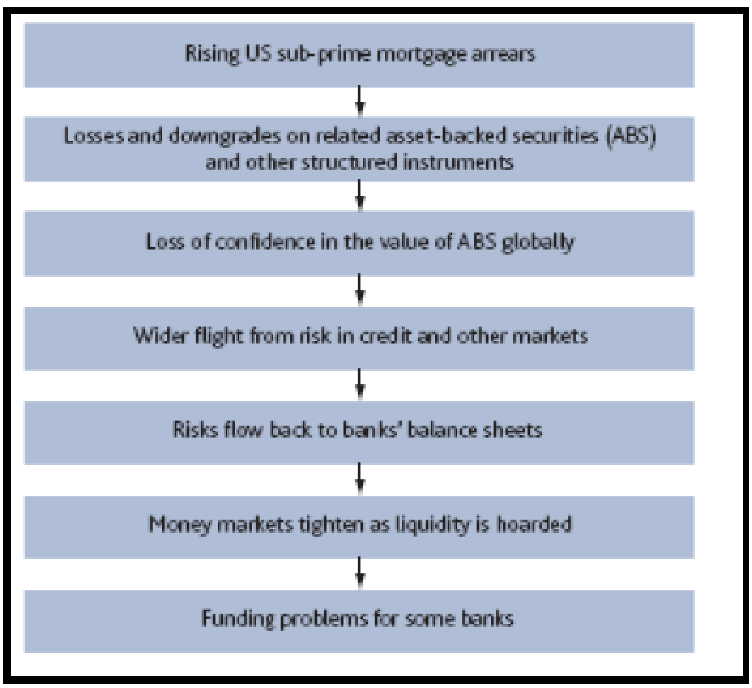
In a nutshell, the credit channel highlights the view that bank loans are different from alternative sources of finance. Because of banks' special ability to deal with small borrowers who lack alternative sources of funding, they can best cope with any problem of informational asymmetries that may be pertinent to small borrowers. Thus, any tightening of monetary policy that reduces the supply of bank loans will starve small borrowers of cash. Ultimately, investment projects will have to be postponed and real output cut back.

A description of the credit channel will be incomplete without mentioning the credit crunch crisis of 2007-2008. What is the relevance of the credit channel for the credit crunch of 2007-2008 ? An interesting fact about this crisis is that it concerns financial intermediaries and financial markets at the initial phases but embeds financial accelerator effects at the latter phases. Through the securitization process, banks in the US and in Europe engaged in financial dis-intermediation by setting up off-balance sheet Special Investment Vehicles (SIVs) that made leveraged investments in asset-backed securities (ABS) and other structured form of financing. Securitization was initially praised for slicing, dicing and transferring credit risks to those agents who had a strong risk-taking appetite and who were ready to handle them. Figure 2.11 (please turn over for illustration) comes from the Bank of England report[9] and intends to illustrate the transmission mechanism throughout the crisis.

The key starting point of the crisis was a rise in default on US subprime mortgages which created substantial losses for these SIVs. The next phase was a general de-leveraging process as mounting losses of confidence were reported globally on the true value of ABSs. Due to complex financial engineering process, it was hard for policymakers or key observers of the financial system, to form an objective opinion about the value of these securities. As risks were re-intermediated in the banking system, banks found it increasingly hard to borrow from each other in the interbank market, partially due to hoarding process. The money market tightened significantly as rates on short-term borrowing mounted in the interbank market and cash-strapped banks found it difficult to raise short-term funding to meet their contractual payment obligations. As a result of being unable to secure liquidity, banks had to cut on their lending policies. This significantly affected firms that relied on bank financing for their investment projects and, through apparent financial accelerator effects, engendered a real collateral damage on the economy.

[9] Bank of England (BoE) Financial Stability Report, October 2007, Issue 22, pp 41.

FIGURE 2.11: The Phases of the Credit Crunch Crisis



2.6 Conclusion

In this chapter, we identified the key market failures responsible for creating and propagating a crisis across banks. Using a well defined taxonomy as depicted in chart 2.1, we have analysed the resulting implications for policy mitigation. The proposed categorisation enables us to round up the main arguments as follows:

[**1**] For models of financial contagion involving multiple banks and direct balance sheet links, the theoretical literature suggests that Central Bankers must pay attention to the network structure as ex-ante crisis prevention measure. If network structure is inappropriate and contagion occurs, then policy measures can be administered at the bank experiencing the initial liquidity shock. Because the contagious effect manifests itself purely from balance sheet links, these policy measures do not represent an externality to other banks in the setup. By preserving the balance sheet of the cash-strapped bank, they preserve the balance sheet of the whole system.

[**2**] When financial contagion involves multiple banks and informational externalities, increased transparency seems to be the key ex-ante measure. Ex-post policy measures may work in pre-empting a crisis at the crisis-catalyst bank but they may have an externality on other banks.

[**3**] Asset price volatility can act as major transmission channel or source of financial fragility, especially if the market for hedging against risks, is incomplete. Excess asset price fluctuations at a time when banks need liquidity the most, may result in an undersupply of liquidity to cash-strapped banks. In this case, repurchase agreements by the Central Bank can be helpful as a corrective mechanism designed to keep asset prices stable.

[**4**] For models of financial fragility based on imperfect information in interbank market, the nature of liquidity underprovision depends crucially on the form of the market imperfection. According to the existing literature, policy measures should commensurate with the particularities of these market imperfections.

The innovative approach embedded within the taxonomy that we have adopted, also enables us to put LOLR activity into perspective. As mentioned in the main parts of this chapter, LOLR may be carried out either to prevent a crisis at one bank from taking systemic proportions or to prevent an illiquidity problem from turning into insolvency. The former argument assumes complete information and can be justified in our taxonomy in the scenario in which banks are contractually linked through the interbank market in deposits. The latter argument takes place in a setting in which there is asymmetric information and can be justified in our taxonomy, where the interbank market may undersupply liquidity to cash-strapped banks due to market imperfections. In some cases, a cost-benefit analysis must be carried out as the Central Bank may be lending to banks that are actually insolvent and illiquid while banks that are solvent but illiquid, may not get the much desired finance.

We have also come across arguments in this chapter showing that, under certain circumstances, financial crises can be benign. They may be good because they discipline bank managers against acting opportunistically (Calomiris and Kahn (1991)); they provide a commitment device to bankers to use their loan negotiation skills on behalf on depositors rather than using these skills for their own personal advantage (Diamond and Rajan (2001a)); they provide contingencies that allow the risk sharing allocation to be achieved (Allen and Gale (1998), (2004)); (in case of multiple banks) they provide a mechanism that induces peer monitoring among banks in the interbank market (Rochet and Tirole (1996)). The main point is that if the by-product of an efficient financial system is a financial fragility or crisis, any attempt to tackle the crisis will impinge on the ability of the financial system to operate efficiently. The material embedded in this chapter will help serve as a valuable screening device for identifying key topics in the literature in which research work is missing. This will provide an important springboard (and motivation) for developing models, which we will do in the subsequent chapters of this thesis, as a way of trying to fill the gaps identified in the literature.

FIGURE 2.12: Financial Crisis Sources

Financial Crisis Initiators	▪ Asymmetric information ▪ Coordination failure problems in depositors' game ▪ Payoff externalities in depositors' game
Financial Crisis Propagators	▪ Network externalities through the presence of an overlapping network of connections (interbank market in deposits and loans) ▪ Informational Spillovers and Correlated fundamentals ▪ Common exposure to fundamentals ▪ Inefficiencies in financial markets, due to incomplete markets and incomplete contracts or market power or asymmetric information ▪ Inefficiencies in Interbank market, due to market power, free-riding, limited commitment

FIGURE 2.13: Financial Crises Triggers

Sunspots or 'extraneous' variables	▪ Arbitrary shifts in expectations lead to coordination failure and to multiple equilibria (Diamond and Dybvig(1983))
Arrival of new information	▪ New (noisy) information sometimes coordinates beliefs and lead to a unique outcome (Chari and Jangannathan (1988), Jacklin and Bhattacharya (1988), Goldstein and Pauzner (2005), Morris and Shin (1998, 2000)) ▪ New information can lead to contagion with interbank exposures (Dasgupta (2004))
Productivity Shocks	▪ Exogenous shocks can lead to coordination failure even in the absence of informational asymmetry (Diamond and Rajan (2001)) ▪ Exogenous shocks are a necessary condition for financial contagion to occur in models with direct interbank exposure (Allen and Gale(2000), Freixas, Parigi and Rochet (2000) ▪ Can trigger banking fragility and currency crises (Aghion, Baccheta, Banerjee (2000)) or financial accelerator (Bernanke and Gertler (1989, 1990), Kiyotaki and Moore (1997))
Financial Shocks	▪ Financial asset price declines can precipitate financial fragility and trigger liquidity problems (Allen and Gale (1998)) and contagion (Donaldson (1992)) ▪ Can trigger banking fragility and financial accelerator (Bernanke and Gertler (1989, 1990), Kiyotaki and Moore (1997))

FIGURE 2.14: Policy Implications

Eliminate Coordination failure	▪ Eliminating coordination failure comes by anchoring expectations on the right outcome: e.g Deposit insurance, Suspension-Of-Convertibility (SOC), promotion of transparency, Capital Requirements.
Promoting efficiency of financial markets and of the interbank market	▪ The idea is to remove market imperfections or any form of hindrances that prevent an efficient provision of liquidity: e.g Using central bank policy intervention, in the form of repurchase agreements, to prevent asset prices from falling
Eliminate any risk of contagion	▪ The idea is twofold: **[1]** appropriate use of policy instruments as crisis prevention and crisis management measurements; **[2]** appropriate design of network structure to make system more resilient to shocks and mitigate the onset of contagion e.g With respect to **[1]**, Lender-Of-Last-Resort (LOLR), bailout guarantees, collateralised requirements for payment systems restrictions of credit exposures; With respect to **[2]**, adopt a 'complete network' as far as possible, to siphon off any possibilities of interbank loss exposures
Reducing impact of the Financial Accelerator	▪ Appropriate use of monetary and fiscal policies in a countercyclical way ▪ (For open countries): Increase interest rates if proportion of foreign-currency denominated debt is high and if elasticity of output with respect to interest rate is low; else, reduce interest rates

Chapter 3

Introduction to Financial Fragility

3.1 Introduction

In this chapter and in the next two, we will be concerned with addressing the first main question we considered in the introduction of this thesis. As a reminder, the question we are considering is the following: "*How can we develop a model that can endogenously distinguish between banking contagion and correlation in probability terms, given that they co-exist in a given banking panic transmission with two banks that have correlated investments?*" We will introduce the formal environment for our banking model in this chapter. The methodological structure of our equilibrium concept will be developed in **chapter 4** and we will discuss the main findings in **chapter 5**.

In settings involving multiple banks with common exposure to a risky sector, a collapse of all banks will legitimately carry symptoms of bank failures due to cross-bank positive correlatedness (*correlated bank failures)* and of banks failing exclusively because others have failed (*contagious bank failures).* The concepts of financial contagion and correlation occur simultaneously and are siamese twins in the process of multiple bank collapse. So far, the literature has failed to provide a robust theoretical account that can realistically enable researchers and practitioners to distinguish between these two fundamental concepts in a given banking panic transmission. Our contribution is meant to close that gap. We are interested in building a model that enables us to detect in probabilistic terms, how far a given banking collapse event can be attributed as one in which the collapse occured solely because the banks are commonly linked to some common fundamental and how far it is one in which one bank's performance has caused the behaviour of depositors of another bank to change so that the other bank fails. When the notion of causation exists, the transmission of a crisis from one bank to another is dubbed *financial contagion*[1].

What motivates our goal to build such a theoretical model ? Globalisation of banking activities is a recent trend that highlights the importance of distilling contagious bank flows from correlatedness. The East Asian crisis of 1997-1998 and the credit crunch crisis of 2007-2008 provide stellar evidence of the fact that banks have common exposure to risky assets and that a given banking failure can assume systemic proportions. While our model is a closed-economy version of a financial system, the following example may be used to help illustrate the intuition behind the motivation of our work: From the point of an individual bank, greater geographical dispersion tends to be associated with better share price performance and better management of idiosyncratic risks. However, while cross-border diversification of banks seems to be associated with greater stability and better risk management practices, the financial system as a whole, may not become more stable with the potential linkages across countries having increased. For economies that have correlated macroeconomic performances, this represents an important aspect of financial fragility especially if they are characterised by heavy cross-bank penetration. In the event of a financial crisis across countries, an ostensible challenge for its policymakers, as part of its overall financial stability programme, will be to dissociate the contagious impact of bank failures from the correlated element of such failures since each element will

[1] See Note C in Appendix (Section A.1) - after the bibliography section at the end of thesis.

warrant a different policy action. The issue of differentiating between correlation and contagion will be a major crux that will be further developed in the subsequent two chapters.

It is the purpose of this chapter to introduce the formal environment of our framework and to highlight the differences between our approach and that adopted by other papers in the literature. In **section 3.2**, we review some notable contributions in the existing literature and we provide additional insights by specifically stessing on the differences and novelty of our approach compared to the existing literature. **Section 3.3** provides an overall synopsis of the banking environment we develop and **Section 3.4** develops the formal environment. Finally, **section 3.5** concludes and provides the build-up for subsequent chapters.

3.2 Unearthing the Transmission Mechanism

3.2.1 Contagion vs Interdependence vs Correlation

'*Real contagion*' or '*direct-link*' models of banking purport that banks are directly connected through the interbank market, either through the exchange of interbank deposits or through the exchange of interbank loans or through the payments and settlements infrastructure. Alternatively, banks may be commonly exposed to some fundamental which directly affects their asset performance. An example of the latter case is the recent deterioration of credit quality of the U.S subprime mortgage market in 2006-2007. With significant number of banks investing in structured mortgage credit products in America, signs of deterioration in credit quality of the subprime segment of the U.S housing sector may deepen and spread to the structured mortgage sector and ultimately affect these exposed banks contagiously. A third branch of real contagion models focus on otherwise dissimilar countries or banks but sharing the same investors (portfolio rebalancing). Most theoretical models of banking contagion with direct links, have been focusing on the first branch.

Leaving aside the banking world, real contagion captures the spread of financial crisis across countries linked through trade and financial flows. Important as these conduits of financial disasters are, these direct linkages were nonetheless weak in contagion of the Tequila crisis from Mexico to Argentina and Brazil in 1994-95, countries in East Asia affected by the crisis of 1997 and the ripple effect of the Russian default in 1998 on many emerging market economies. This inability of real contagion models to explain the recent propagation of financial crises across emerging markets, makes the case for 'pure contagion' models stronger as natural candidate offering pertinent explanation of these events.

Models of '*pure contagion*' stress on the different uses of information, as possible channel explaining how a failure may propagate from one bank to another, even though banks are not directly linked through fundamentals. The basic mechanism propagating shocks across banks is the shift in investor sentiment through changes in perceptions. Some of the leading explanations for financial contagion, especially after the Russian default of 1998, are based on changes in 'psychology', 'attitude', 'investor behaviour'. In fact, many economies that have experienced financial contagion recently had strong macroeconomic fundamentals and blame the contagious effects they have suffered on the 'harmful and corrupting' influence of investor psychology in other countries.

The interested reader is requested to read **chapter 2** of this thesis for an idea of pure and real contagion papers in the literature of banking theory. A natural conundrum in building theoretical models of financial contagion is to elaborate on the precise concept of contagion to be adopted. The latter is crucial for explaining the nature of the transmission mechanism and for the design of key policies required to contain the undesirable effects. There is considerable ambiguity concerning the precise definition of contagion and different interpretations of contagion have been provided in the literature. There is no theoretical or empirical definition on which economists agree.

Direct-link theories stress on a fundamental-based definition of contagion, often interpreted as the propagation of shocks through direct linkages connecting banks. This definition nonetheless stresses on the existence of an underlying transmission mechanism that remains the same in all states of the world: *'non-tranquil' states* and *'tranquil' states*. Thus, direct-link models will describe the transmission of a a crisis from Brazil to Argentina, for example, as a case of contagious flow. The Argentinean stock market rose and fell with the Brazilian market during the crisis of 1999. Brazil and Argentina are located in the same geographical region, are at the same stage of economic development, have many similarities in terms of their market structure and in their trade and financial links patterns. In all states of the world, these two economies remain strongly connected. Thus, it is not surprising that a negative shock in Brazil is strongly passed on to Argentina. If such a transmission represents merely a continuation of the same cross-market linkages that exist in tranquil and non-tranquil times, then this crisis does not represent contagion, but rather interdependence. Nonetheless, direct-link theories will describe this as a case of contagion.

In an empirical study of European interest rates, Pesaran and Pick (2007) highlight the importance of distinguishing between interdependence and contagion for econometric purposes. The distinction between these two concepts has not been considered by theoretical models of contagion. In Allen and Gale (2000) and Dasgupta (2004), banks cross-hold deposits as insurance against regional liquidity shocks. The main channel of panic transmission is the interbank market in deposits and cross-bank linkages remain the same before and after a crisis. The main point of such 'interdependence' is that in tranquil periods, the interbank market provides the channel for cross-regional insurance but in crisis periods, the interbank market provides the main conduit that spreads a crisis from bank to bank..

We construct a microfounded model of contagion that is a theoretical adaption of the observation of Pesaran and Pick (2007) and we bypass key conceptual problems by adopting a modelling structure that yields contagion as a concept that approaches the spirit of "*shift contagion*", concocted by Forbes and Rigobon (2002). Working on observed trends in Latin America depicting a high degree of comovement within Latin American economies and across emerging markets in general, especially the bonds market, Forbes and Rigobon (2002) describe contagion as one in which the cross-market linkages across countries increase during a crisis period compared to that of a normal period - the notion of "shift contagion". Thus, in a world with comovements in asset prices, contagion will only be taken to represent the case when there is an increase in this correlatedness in certain states of the world (crisis periods) as compared others (normal periods). Cases in which the cross-market linkages remain unaffected and continue to exist in all states of the world, are cases which merely illustrate interdependence not contagion[2]. Our approach intends to be a major *tour-de-force* in the literature of banking panic transmission by providing a state-of-art account of contagion ā-la Forbes and Rigobon (2002), while addressing a number of economic issues that have been confined to oblivion - and which we believe, are at the core of any study of banking panic transmission.

3.3 Brief Summary of our Banking Environment

The banking environment can be summarised as follows: there are two banks in the economy, each of which spans a particular region of the economy. At the initial period, $t = 0$, depositors in both regions invest their endowment in the bank of their region. These depositors face liquidity shocks of the Diamond-Dybvig (1983) type and can consume early or late. There is no aggregate uncertainty about liquidity shocks in the model. In return for accepting deposits, banks offer depositors demand deposit contracts that allow depositors to withdraw either in the interim period $t = 1$ or the final period $t = 2$, depending on the realisation of the liquidity shock (which is only known at the beginning of

[2] See note F in Appendix (Section A.1).

period $t = 1$). Both banks invest in a hedge fund, which consists of two risky portfolios, one for each bank, at $t = 0$. The performance of each bank's portfolio depends on the bank's idiosyncratic fundamental (e.g the quality of the bank's management) as well as a common macroeconomic fundamental to which both banks are positively exposed.

Each bank's idiosyncratic fundamental and the common macroeconomic fundamental are not common knowledge, although their probability distributions are at time $t = 0$. Depositors in each bank noisily observe their bank's idiosyncratic fundamental through some *private signal structure*. For each depositor of a given bank, this private signal contains information about his bank's idiosyncratic fundamental as well as strategic information on the behaviour of other depositors of the same bank. For the sake of simplicity, we shall denote this coordination game between depositors, as $\Gamma_{A,t=1}$and $\Gamma_{B,t=1}$ for bank A and B respectively.

Furthermore, in the spirit of dynamic Bayesian games, nature picks up at random the first movers of the game. We will assume that depositors in bank A move first and depositors in bank B move second. The latter depositors observe a public information encapsulating the event in bank A. Depositors are Bayesian agents. Due to incomplete information of the game structure (depositors in bank B do not know whether those in bank A do not observe the common fundamental), we assume that they use the public information about bank A as a strategic learning tool to update their beliefs about the state of the common macroeconomic fundamental. Along the equilibrium path, each group of depositors plays a best-response action. Those in bank A play a best response after observing their private signals about their bank's idiodyncratic fundamentals and after taking into account the prior probability of the common macroeconomic fundamental. Those in bank B play a best response after observing their private signals and the event in the first bank. The event in the first bank actually leads them to update their prior beliefs about the state of the common macroeconomic fundamental so that their bank may face a similar fate as the first bank. The mechanics of beliefs updating by depositors of the second bank, constitutes the informational spillover mechanism in our setup. In the presence of correlated risky investment, an interesting aspect of this approach is to consider the circumstances in which bank B will if and only if bank A has failed. In subsequent two chapters, we use this foundation to develop a theoretical paradigm that enables us distill between the contagious and the correlated elements in a given banking crisis transmission process.

Our approach differs from the existing papers of banking contagion in the literature on a number of fronts. Like in Dasgupta (2004), we consider a banking environment with two banks and we use the global games approach to characterise the existence of a trigger equilibrium. Allen and Gale (2000) and Chen (1999) do not use the global games approach to pin down the existence of equilibrium. Dasgupta (2004) considers two uncorrelated banks that are essentially linked through the interbank market channel. Our modelling structure is different because there are no direct links (like interbank market) across banks and we allow banks to be naturally correlated from their portfolio investment. Another difference with Dasgupta (2004) is that we allow for strategic interractions between depositors of the two banks. The presence of dynamic Bayesian structure with private signals for depositors of each bank and a public signal that enables strategic inferences for depositors in the second bank, allows for such strategic interractions. We model the public signal as a strategic informational spillover mechanism for depositors of the second bank. In Dasgupta (2004), the event in the first bank is not a publicly observable variable to depositors of the second bank. Thus, there are no informational spillovers. This leads to the absence of strategic interractions between depositors of the two banks. An important consequence of this is that the derivation of the equilibrium is done in Dasgupta (2004), assuming there is only one bank. Thus, even though there are two banks, the nature of the game is similar to that of a static coordination game of incomplete information. Our dynamic approach is more complicated due to the presence of strategic interractions across banks and we are bound to consider the links between a dynamic equilibrium concept and trigger equilibrium. Studying these notional issues of equilibrium, by itself, constitutes an important contribution that we make to economic theory and, is the treatise of **chapter 4**.

Our equilibrium concept is different to Dasgupta (2004). Like in Allen and Gale (2000), Dasgupta (2004) explains contagion as an event that takes place across banks through the interbank market channel. Thus, the concept of contagion is explained from the perspective of 'interdependence'. Our approach explains contagion from the perspective of 'excess correlation', which has been shown to be a more robust concept of contagion, following the work of Forbes and Rigobon (2002) and of Pesaran and Pick (2007). Furthermore, our innovative approach enables us to simultaneously explain three puzzles in the literature of contagion which we will explain in details in **chapter 5**. These puzzles include: **[1]** (*zero-Link puzzle*) contagion spreads across banks that are not connected directly; **[2]** (*clustering puzzle*) contagion tends to be clustered among identical banks only; **[3]** (*avoidance puzzle*) among identical banks, some can avoid a contagious failure whereas others cannot. Allen and Gale (2000) and Dasgupta (2004) cannot explain the three puzzles since, by construction, the banks in these models (all identical) are always connected by the interbank market. Furthermore, compared to single-bank models like Diamond and Dybvig (1983), Allen and Gale (2000) and Dasgupta (2004) do not add additional insights to the nature and design of policies that Central Banks should implement at crisis-catalyst banks. Our dynamic approach with interractions across banks and informational spillovers, allows us to contribute to the debate about the nature of policymaking in a way that is not captured by single-bank models. We conjecture that, in a two-bank setting, the presence of public signals may mean that policy implemented at one bank, leads to *'intertemporal substitution of banking crisis'* in the economy. We conjecture that this contribution places our model very well to explain the recent Northern Rock financial crisis of 2007, compared to alternative models in the literature.

Another important work in the existing literature is the work of Chen (1999). The latter considers informational spillovers through Bayesian updating across two banks. Our paradigm differs from Chen (1999) on a number of fronts. Chen (1999) does not use equilibrium selection techniques to get rid of multiplicity of equilibria. As we explained in **chapter 1**, allowing for multiplicity of equilibria poses a problem for modelling financial contagion. If a model is silent about the occurrence of a particular outcome in one bank, it cannot explain how an event will flow from one bank to another as an equilibrium event. Chen (1999) uses strong assumptions to get rid of this problem. While acknowledging the existence of multiple equilibria in the first bank, the model analyses the transmission of a crisis based on informational spillovers while assuming a given event in the first bank. Our approach is more robust since we are capable of getting rid of multiplicity of equilibria automatically through the global games approach. Furthermore, unlike Chen (1999), we have a dynamic Bayesian structure with strategic interractions across banks. Finally, our rigorous theoretical underpinning enables us endogenously distinguish between the correlated and contagious elements of a given crisis in probability terms. Chen (1999) does not consider this distinction. Finally, our approach enables us to make events across banks (correlation vs contagion), a function of the vital interplay between private signals and the public signal. We are capable of relating a contagious event to some underlying informational structure in the banking system. This is completely new to the literature of banking contagion[3].

Figure 3.1 (please turn next page) summarises these main differences between our approach and that of other key contributions in the literature.

[3] Hellwig (2002) considers a similar question in a stylized static coordination game of incomplete information. We will turn to this idea in more details in **chapter 5**.

FIGURE 3.1: How Different is Our Approach to the Existing Literature?

	Our Approach	**Allen and Gale (2000)**	**Dasgupta (2004)**	**Chen (1999)**	**Vaugirard (2005)**	**Rochet and Tirole (1996)**
Number of Diamond-Dybvig (1983) Banks	Two Banks	Four Banks	Two Banks	Multiple Banks	Multiple Banks	Multiple Banks
Mission Statement	Distinguish between Contagion and Correlation in equilibrium	Equilibrium Contagion as Function of Interbank Market	Derive Optimal Interbank Contract as a Trade-off Between risk-Sharing and Probability of Contagion	Introduction Of Informational Spillovers in the Diamond-Dybvig (1983) setup	Introduction Of Informational Spillovers in the Diamond-Dybvig (1983) setup	Analysis of Contagion as incentive Device to monitor banks
Structure of Game	Dynamic Bayesian Setting	No Strategic considerations Across Banks	Dynamic Bayesian Setting	No Strategic considerations Across Banks	No Strategic considerations Across Banks	No Strategic considerations Across Banks
Information of Depositors	Private and Public Signals (Bayesian Assessment)	No Signals	Private Signal ONLY	No Signals (except Bayesian Assessment)	No Signals (except Bayesian Assessment)	No Signals
Nature of Spillover Across Banks	Informational Spillover Across Banks	Interbank Market in Deposits	Interbank Market in Deposits	Informational Spillover	Informational Spillover	Interbank Market in Loans
Methodology	Global Games Methodology (Dynamic) No Multiple Equilibria	Multiple Equilibria Possible	Global Games Methodology (Static) No Multiple Equilibria	Multiple Equilibria - A Possibility	Global Games Methodology (Static) No Multiple Equilibria	N / A

3.4 The Model

The economy is divided into two ex-ante identical regions, A and B. The regional structure can be a spatial metaphor. There are three periods, $t = 0, 1, 2$. Each region contains one commercial bank which accepts deposits of money from consumers and invest the proceedings in different technologies. There is a continuum of risk-neutral consumers having strictly increasing and linear preference functions, and, being depositors in the bank of their region. As in the literature of bank runs, the set of depositors can be represented by a unit interval $[0, 1]$ with measure equal to one and the fraction of agents in any subset can be represented by its Lebesgue measure. Each agent lives for three periods only and is endowed with one unit of a homogeneous good at $t = 0$ and deposits his endowment in the bank of his region at $t = 0$. The alternative to investing in the bank would be for each depositor to costlessly invest in some external storage technology that yields a return of 1 at time $t + 1$ unit for each unit deposited at time t. We assume that there is no Central Bank and no financial markets in the model and that only banks have a comparative advantage in providing liquidity.

3.4.1 Returns Stucture and Bank's Investment Technologies

Each bank can either invest in a safe-and-liquid technology or in a risky-and-illiquid technology. One unit deposited at t yields exactly one unit at $t + 1$ under the safe-and-liquid technology. This technology could represent cash reserves that the banks have to keep (by statutory liquidity requirements) to meet demand for early withdrawals[4]. The risky-and-illiquid technology could be viewed as a hedge fund and its returns structure is more extricate: we assume that the hedge fund consists of two risky portfolios and each bank invests in

[4] Thus, the banking system we are referring to here is a fractional reserve system.

one of the risky portfolios. The returns of each portfolio in the hedge fund, will be assumed to be positively related. More specifically, the portfolio of bank i yields a return of $\tilde{R}_i$ in period $t = 2$, where θ_i is regarded as the idiosyncratic fundamental of bank i. Thus, for banks A and B, returns $\tilde{R}_A$ and $\tilde{R}_B$ will be realised in period $t = 2$ under their risky technologies, and $\tilde{R}_A$ and $\tilde{R}_B$, will be assumed to be positively linked to some exogenous macroeconomic fundamental, u. Each bank's risky investment technology is divisible and can be liquidated in the interim period to meet, say, the excess demand for early withdrawals. We assume that if bank i liquidates its portfolio in period $t = 1$, it obtains an exogenous return of r (< 1) from the liquidated portfolio [5]- meaning that there are costs to early liquidation. Furthermore, for bank i, the returns from the risky portfolio of the hedge fund, can be $0, R_{\max}, \tilde{R}_i$,depending on the relationship between model parameters. This is nicely summed up in Figure 3.2:

FIGURE 3.2: Returns Structure of the Risky Portfolio for Bank i

If investment is liquidated prematurely, the return is: $r < 1$ at time $t = 1$

If investment is carried on till time $t = 2$

$$\tilde{R}_i = \left\{ \begin{array}{ccc} R_{\max} & if & \theta_i > u + z\delta_i \\ \tilde{R}(\theta_i, u) & & u \leq \theta_i \leq u + z\delta_i \\ 0 & & \theta_i < u \end{array} \right\}$$

where $0 < \tilde{R}_i < R_{\max}$

Interpretation:

[5] Thus, our emphasis on the positive link between $\tilde{R}_A$ and $\tilde{R}_B$, holds in period $t = 2$ only. If bank A prematurely liquidates its portfolio and earns r, this does not mean that bank B will have to liquidate its asset in the hedge fund as well.

Let $j = \{G, Bad\}$ denote $\{Good\ State,\ Bad\ State\}$ and $i = \{A, B\}$ denote $\{Bank\ A,\ Bank\ B\}$.

[1] We distinguish between two fundamentals that are relevant for our analysis: each bank's *idiosyncratic fundamental* and a *macroeconomic fundamental* that is common to both banks. Parameter θ_i simply denotes bank i's idiosyncratic fundamental. We assume that it is drawn randomly from some *uniform density* on a unit interval. Each depositor in bank i can only noisily observe θ_i but the underlying probability distribution supporting θ_i is common knowledge to all depositors. We also make the important assumption that, once a value for θ_i is realised at $t = 0$, it does not change throughout the whole experiment. We return to a more formal analysis of each bank's idiosyncratic fundamental in section 3.1.

[2] Parameter u represents the state of some macroeconomic fundamental that affects each bank. It is independent of a bank's idiosyncratic fundamental, θ_i. The two distinguishing features of u are as follows: (i) it represents either a Good (denoted 'G') or Bad (denoted 'Bad') macroeconomic state that affects each bank . If a particular state of the world occurs, it affects both banks in the same way. For e.g, if the state of the common macroeconomic fundamental is bad, it will be so for both banks. The exact realisation of the state of the common macroeconomic fundamental is not observed by depositors but the (prior) probability distribution underlying the binary states is common knowledge. For simplicity, we assume that $P(u^{Bad}) = 1 - P(u^{G}) = k$, with $u^{Bad} > u^{G}$. The common macroeconomic fundamental is realised at $t = 0$ and we assume that its realisation (which is never observed) remains stationary throughout the experiment[6];(ii) because of the assumption enshrined in (b) (i), it follows that there is an implicit positive linkage between the returns of $\tilde{R}_A$ and $\tilde{R}_B$ in that, both $\tilde{R}_A$ and $\tilde{R}_B$, move in the same direction with the common fundamental.

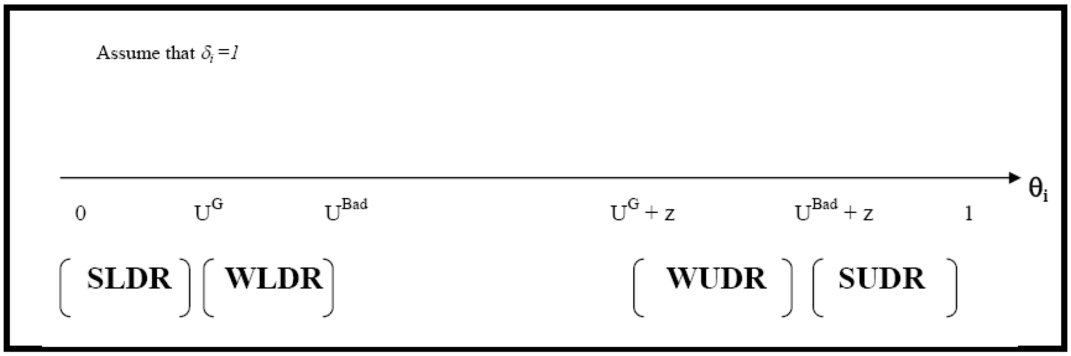
[6] The state of the common fundamental can never shift between good and bad throughout our experiment.

[3] Parameter z denotes the loss caused by premature early withdrawals of deposits from the bank, where the proportion of early withdrawals by patient depositors is denoted by δ_i, $0 \leq \delta_i \leq 1$. The greater z is, the greater the disruption caused and the greater is the likelihood that $u + z\delta_i$ is high relative to the particular realisation of θ_i for bank i. Note that, by adopting the specification as in Table 1, one can see that, for extreme values of the idiosyncratic fundamental θ_i,the returns to the long asset depend exclusively on the value of the idiosyncratic fundamental θ_i. Before moving further, we make the following structural assumptions about parameter values: [**a.1**] $u^G > 0$, [**a.2**] $u^{Bad} + z < 1$, [**a.3**] $u^{Bad} < u^G + z$, [**a.4**] $P(u^{Bad}) = 1 - P(u^G) = k$, [**a.5**] $P(u^{Bad}) > P(u^G)$ with $u^{Bad} > u^G$.

3.4.2 Dominance Regions

A '*worst case*'scenario is one in which the state of the common macroeconomic fundamental is bad (u^{Bad}) and everybody withdraws money from the bank ($\delta = 1$); if θ_i is high enough that it exceeds $\{u^{Bad} + z\}$, then Figure 3.3 suggests that the returns to the investment project should be $R_{\max}$. This suggests that even in the worst case scenario when every depositor withdraws prematurely, θ_i is strong enough to be dominant (i.e determines long term returns.) In the '*best case'* scenario (i.e one in which the state of the common fundamental is good (u^G) and nobody withdraws prematurely (i.e $\delta_i = 0$), the risky project for bank i may still fail if the value of θ_i is so low that it lies below u^G. These case scenarios depict an important result for the returns structure of the risky-and-illiquid technology: Regions $\left\{\theta_i : [\theta_i > u^{Bad} + z] \cup [\theta_i < u^G]\right\}$ depict those segments of the $\theta_i - space$ for which θ_i is strictly dominant i.e can always ruin or save the risky project and become the overriding determinant of the risky technology. The intermediate region $\left\{\theta_i : u^G \leq \theta_i \leq u^{Bad} + z\right\}$ rules out any possibility of θ_i dominance and an interraction between different model parameters will determine the outcome of the project.

FIGURE 3.3 : Segregation of the θ_i - space into Strict and Weak Dominance Regions



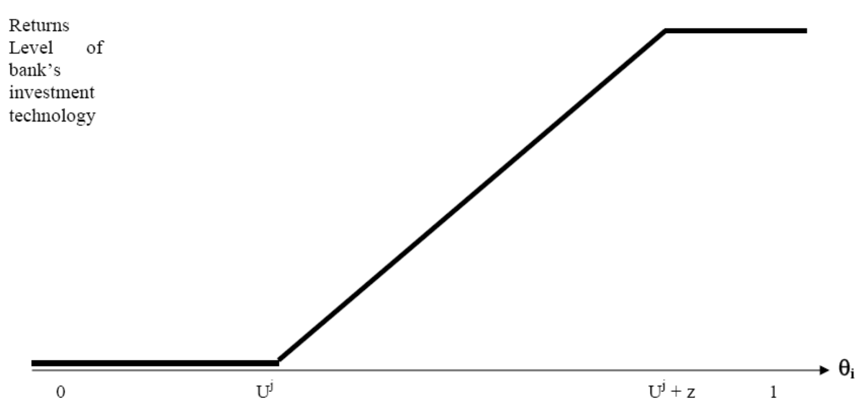
Given assumptions [**a**.**1**] – [**a**.**5**] above, we summarise the following features of $\tilde{R}_i$ for any bank i: [**a**] $\forall\ \theta_i < u^G,\ \tilde{R}_i = 0$, [**b**] $\forall\ \theta_i > u^{Bad} + z,\ \tilde{R}_i = R_{\max}$, [$c$] $\forall\, \theta_i$ s.t $\{u \leq \theta_i \leq u + z\}$, where either states of u may be realised, $\tilde{R}_i$ has the following properties: [**c**.**1**] For fixed θ_i, $\tilde{R}_i$ decreases with the common fundamental getting into its bad state (see Figure 3.4 (b) at the end of this chapter) - what this is saying is that, for some bank i, moving from a good state (u^G) to a bad one (u^{Bad}) will lower returns, other factors remaining fixed ; [**c**.**2**] for a fixed realisation of the common macroeconomic fundamental, $\tilde{R}_i$ increases with θ_i in the relevant range of fundamentals being considered (see Figure 3.4 (a) on next page); [**c**.**3**] for fixed θ_i and fixed state of the common fundamental, $\tilde{R}_i$ rotates downwards with z (see Figure 3.4 (c) at the end of this chapter); [**c**.**4**] for fixed θ_i, a decrease in the proportion of early withdrawals by depositors, δ_i, will rotate $\tilde{R}_i$ upwards (see explanation on Figure 3.4 (d) in the graphical appendix); [**c**.**5**] for a given state of the common macroeconomic fundamental , as $\delta_i \to 0, \tilde{R}_i \to 0$ iff $\theta_i \to u$; as $\delta_i \to 1$, $\tilde{R}_i \to R_{\max}$ iff $\theta_i \to u + z$. [Figures 3.4 (b)-(d) in the graphical notes that appear at the end of this chapter, show the relationship between the returns structure of bank i's risky portfolio and different fundamentals.]

FIGURE 3.4 (a) : The Relationship between Idiosyncratic Fundamental, Common Macroeconomic Fundamentals and (risky) Returns Technology for a Bank

Assume:

[1] State of the Common Macroeconomic fundamental: j

[2] $\delta_i = 1$



3.4.3 Payoff Structure to Depositors in Each Bank

As in all models of bank runs, we assume that depositors in each bank face '*liquidity preference shocks'* i.e each of the depositors can consume early (i.e at $t = 1$) with probability λ and late (i.e at $t = 2$) with probability $1-\lambda$. There is a privately observed uninsurable risk of being patient or impatient, with there being no aggregate liquidity uncertainty in the economy. The probability distribution of liquidity preference shocks is assumed to be common knowledge. Ex-ante, each depositor has an equal and independent chance of being of impatient type. Thus, for each bank, the proportion of impatient depositors is λ and the proportion of patient depositors is $1 - \lambda$. It is at the beginning of period $t = 1$ that depositors learn their type.

In return for accepting depositors' money endowments, each bank offers *demand deposit contracts* to depositors. There are two states of the world to be contrasted for modelling these contractual obligation payments. Before proceeding to a formal analysis of these states, let's turn to characterisation of the bank's optimal investment plan at time $t = 0$ under the assumption that there is no bankruptcy. We temporarily assume that the deposit contract promises to pay c_1 to impatient depositors and a stochastic amount c_2 to patient depositors. We also assume that by adopting this term structure of demand deposit payments, the bank implicitly satisfies the participation constraints of depositors and induces them to invest their endowments in period $t = 0$ in the bank rather than in some external storage technology. Each bank has an asset portfolio comprising a fraction of y being earmarked to its short-and-liquid asset and x to its long-and-illiquid asset. The portfolio satisfies the constraint that $x + y = 1$. While depositors face uncertainty ex-ante about their liquidity needs, banks do not face such uncertainty. The liquidity needs for depositors are mutualised so that, by the law of large numbers, the banks can reasonably expect a fraction λ of depositors to withdraw early and a fraction $1 - \lambda$ to withdraw late. Thus, each bank chooses its portfolio plan such that, in period $t = 1$, $\lambda c_1 = y$. Absent bank runs, the amount paid to impatient depositors must satisfy the participation constraint provided by the external storage technology[7] i.e $c_1 = 1$. Due to the resulting equivalence between λ and y , each bank can earmark a fraction λ to its liquid asset and a fraction $1 - \lambda$ to its illiquid asset[8].

What if there is not enough cash available to meet the demand for withdrawals in period $t = 1$? In this case, the bank is compelled to liquidate its risky asset and to divide the resulting proceeds of the liquidated asset equally among those who have chosen to withdraw early. We consider some definitions before engaging in formal analysis of deposit payments.

Definition 3.1 (**Banking Crisis**) The bank enters a state of crisis if it is forced to liquidate its long-and-risky asset.

[7] Given our earlier assumption on risk neutrality, the need to provide insurance to impatient depositors disappears.

[8] For the rest of the paper, we shall drop c_1 and c_2, and replace them directly by the amounts that these parameters command from the bank's balance sheet.

Definition 3.2 (Bankruptcy Zone) Bank i stops being a going-concern at $t = 2$ if and only if it is in a state of crisis as per definition 1 and if $\{\lambda + \delta_i(1-\lambda)\} > \{\lambda + r(1-\lambda)\}$ i.e if $\delta_i > r$ in the first period.

Definition 3.3 (**No Bankruptcy Zone**) A bank that is in crisis as per definition 1, continues to be a going-concern in period $t = 2$ if $\delta_i \leq r$[9] in the first period.

Following the previous discussion, a proportion λ of depositors in bank i is impatient. Suppose that a proportion δ_i of the patient depositors wants to withdraw at $t = 1$. The total demand for liquidity that bank i faces is thus $\{\lambda + \delta_i(1-\lambda)\}$ .Where does the bank draw its supply of liquidity to meet high early demand? It has λ in the liquid technology. It may also draw upon its illiquid technology and use the resulting proceeds to meet high demand for early withdrawals. The total supply of liquidity is thus $\{\lambda + r(1-\lambda)\}$[10]. If the total demand for early withdrawals exceed the available pool of assets that the bank can make available, then the bank is technically bankrupt at $t = 1$. This helps us characterise the bankruptcy threshold of the bank.

The importance of the bankruptcy threshold is that it determines the term structure of payments allocation for depositors as well as the 'liquidation' rule for the risky asset. The concept of liquidity rule is self-explanatory. In the bankruptcy zone, the whole risky asset is liquidated when patient depositors choose to withdraw early. Thus, there are no leftovers for those who have chosen to stay till period $t = 2$. In the no-bankruptcy zone, only a fraction of the risky asset is liquidated. The remaining portion is carried forward till period $t = 2$. Suppose that $\delta_i > r$ (i.e *Bankruptcy condition*). Depositors who choose to withdraw early appropriate the whole proceeds that the bank can generate at $t = 1$. Each depositor gets an amount $\frac{\lambda + r(1-\lambda)}{\lambda + \delta_i(1-\lambda)}$,with utility $U\left[\frac{\lambda + r(1-\lambda)}{\lambda + \delta_i(1-\lambda)}\right]$. Since $\delta_i > r$, clearly, $\frac{\lambda + r(1-\lambda)}{\lambda + \delta_i(1-\lambda)} < 1$. Utility functions, being an increasing

[9] Thus, a bank in crisis may still carry on operation provided it has enough to pay all those who claim back their deposits.

[10] Technically, the amount supplied should be represented as $\{y + r(1-y)\}$.

function of payoffs, this implies $U\left[\frac{\lambda+r(1-\lambda)}{\lambda+\delta_i(1-\lambda)}\right] < U(1)$. The depositor is worse off than when he received his full endowment back. Those patient depositors who do not choose to imitate the impatient ones and who have chosen to withdraw at $t = 2$, get a payoff of zero, with utility $U(0)$.

Suppose now that $\delta_i \leq r$ (i.e *No-Bankruptcy condition*). Those depositors who claim early withdrawals get their whole endowment back with utility $U(1)$. With this condition, to satisfy the demand for early withdrawals, only a proportion of illiquid assets has to be liquidated and is $\frac{\delta_i(1-\lambda)}{r}$. The leftover of illiquid assets that is carried on till $t = 2$ to finance the withdrawals of patient depositors is thus: $\left\{(1-\lambda) - \frac{\delta_i(1-\lambda)}{r}\right\}\tilde{R}_i$. Each of the patient depositors shares this leftover, appropriated by the exact proportion of depositors who are claiming this leftover. Each depositor thus gets $\left[\frac{\left\{(1-\lambda)-\frac{\delta_i(1-\lambda)}{r}\right\}\tilde{R}_i}{(1-\lambda)(1-\delta_i)}\right]$ with utility $U\left[\frac{\left\{(1-\lambda)-\frac{\delta_i(1-\lambda)}{r}\right\}\tilde{R}_i}{(1-\lambda)(1-\delta_i)}\right]$. To summarise, the payoff structure for each depositor of bank i takes the following form:

Demand Deposit Contract Payments in a Banking Crisis State: Bankruptcy ($\delta_i > r$) vs Non-Bankruptcy Zone ($\delta_i \leq r$)

• For impatient depositors and the proportion of patient depositors who choose to withdraw early:

$$U_{t=1} = \left\{ \begin{array}{ll} U(1) & \delta_i \leq r \\ U\left[\frac{\lambda+r(1-\lambda)}{\lambda+\delta_i(1-\lambda)}\right] & \delta_i > r \end{array} \right\}$$

• For the proportion of patient depositors who withdraw late:

$$U_{t=2} = \left\{ \begin{array}{ll} U\left[\frac{\left\{(1-\lambda)-\frac{\delta_i(1-\lambda)}{r}\right\}\tilde{R}_i}{(1-\lambda)(1-\delta_i)}\right] & \delta_i \leq r \\ U(0) & \delta_i > r \end{array} \right\}$$

Demand Deposit Contract Payments in a Non-Banking Crisis State:

• For impatient depositors,

$$U_{t=1} = U\left(1\right)$$

- For patient depositors

$$U_{t=2} = U\left(R_i\right)$$

The following table summarises the relationship between the net payoff to staying for a typical depositor of a bank as a function of the two states of the world:

FIGURE 3.5 : Net Payoff to Withdrawing

	No Banking Crisis	**Banking Crisis**	**Banking Crisis**
		NBC	BC
	$\boldsymbol{\delta = 0}$[11]	$\boldsymbol{\delta \leq \mathbf{r}}$	$\boldsymbol{\delta > \mathbf{r}}$
Staying	$U\left(R\right)$	$U\left[\frac{\left\{(1-\lambda)-\frac{\delta(1-\lambda)}{r}\right\}\tilde{R}}{(1-\lambda)(1-\delta)}\right]$	$U(0)$
Withdrawing	$U\left(1\right)$	$U(1)$	$U\left[\frac{\lambda+r(1-\lambda)}{\lambda+\delta(1-\lambda)}\right]$
Net Payoff	$U\left(R\right)$ $-U\left(1\right)$	$U\left[\frac{\left\{(1-\lambda)-\frac{\delta(1-\lambda)}{r}\right\}\tilde{R}}{(1-\lambda)(1-\delta)}\right]$ $-U(1)$	$U(0)$ $-U\left[\frac{\lambda+r(1-\lambda)}{\lambda+\delta(1-\lambda)}\right]$

3.4.4 Structural Parameter Restrictions and Features of Payoff Structure

Under the Bankruptcy-Condition (BC) with $\delta_i > r, \quad U\left[\frac{\lambda+r(1-\lambda)}{\lambda+\delta_i(1-\lambda)}\right] > U(0)$. This result holds sway because of the feature that $0 \leq \frac{\lambda+r(1-\lambda)}{\lambda+\delta_i(1-\lambda)} \leq 1$. The net payoff to staying as opposed to withdrawing is therefore negative in the BC threshold.

[11] No patient depositors withdraw early and no risky asset is liquidated prematurely.

Under the No-Bankruptcy-Condition (NBC) with $\delta_i \leq r$, the relationship between $U\left[\frac{\left\{(1-\lambda)-\frac{\delta_i(1-\lambda)}{r}\right\}\tilde{R}_i}{(1-\lambda)(1-\delta_i)}\right]$ and $U(1)$,depends on the location of δ_i in the NBC segment. More precisely, there exists a $\delta^{\#}$ $\left(\text{equal to } \frac{r\left(\widetilde{R}-1\right)}{\widetilde{R}-r}\right)$, at which $U\left[\frac{\left\{(1-\lambda)-\frac{\delta_i(1-\lambda)}{r}\right\}\tilde{R}_i}{(1-\lambda)(1-\delta_i)}\right] = U(1)$. For $0 \leq \delta < \frac{r\left(\widetilde{R}-1\right)}{\widetilde{R}-r}$, $U\left[\frac{\left\{(1-\lambda)-\frac{\delta_i(1-\lambda)}{r}\right\}\tilde{R}_i}{(1-\lambda)(1-\delta_i)}\right] >$ $U(1)$. Thus, it is strictly preferable to stay. For $\frac{r\left(\widetilde{R}-1\right)}{\widetilde{R}-r} \leq \delta < r, U\left[\frac{\left\{(1-\lambda)-\frac{\delta_i(1-\lambda)}{r}\right\}\tilde{R}_i}{(1-\lambda)(1-\delta_i)}\right] <$ $U(1)$. Here, it is strictly preferable to withdraw[12]. The relationship between the payoff to staying and payoff to withdrawing, can be shown in Figure 3.6 (please turn over for illustration).

3.5 Information Structure

3.5.1 Private Signal structure

As mentioned before, we assume that depositors cannot observe the idiosyncratic fundamental of their bank and do not observe the actual realisation of the common macroeconomic fundamental. While impatient depositors in each bank have a *dominant strategy* of withdrawing in period $t = 1$, patient depositors face a coordination problem in period $t = 1$ as regards their decision of whether to stay or withdraw. Their decision is based on their informational endowment at

[12] Here is the proof: Since $U[.]$ is linear and strictly increasing, condition $U_i\left[\frac{\left\{(1-\lambda)-\frac{\delta_i(1-\lambda)}{r}\right\}\tilde{R}_i}{(1-\lambda)(1-\delta_i)}\right] = U_i(1)$ implies that $\frac{\left\{(1-\lambda)-\frac{\delta_i(1-\lambda)}{r}\right\}\tilde{R}_i}{(1-\lambda)(1-\delta_i)} = 1$. Making δ_i subject of formula, will lead to the following: $\delta^{\#} = \frac{r\left(\widetilde{R}-1\right)}{\widetilde{R}-r}$. Since $U_i\left[\frac{\left\{(1-\lambda)-\frac{\delta_i(1-\lambda)}{r}\right\}\tilde{R}_i}{(1-\lambda)(1-\delta_i)}\right]$ is decreasing in δ_i, it follows that for $\delta_i < \delta^{\#}$, $U_i\left[\frac{\left\{(1-\lambda)-\frac{\delta_i(1-\lambda)}{r}\right\}\tilde{R}_i}{(1-\lambda)(1-\delta_i)}\right] > U_i(1)$. A similar analysis will show that $U_i\left[\frac{\left\{(1-\lambda)-\frac{\delta_i(1-\lambda)}{r}\right\}\tilde{R}_i}{(1-\lambda)(1-\delta_i)}\right] < U_i(1)$ if $\delta_i > \delta^{\#}$

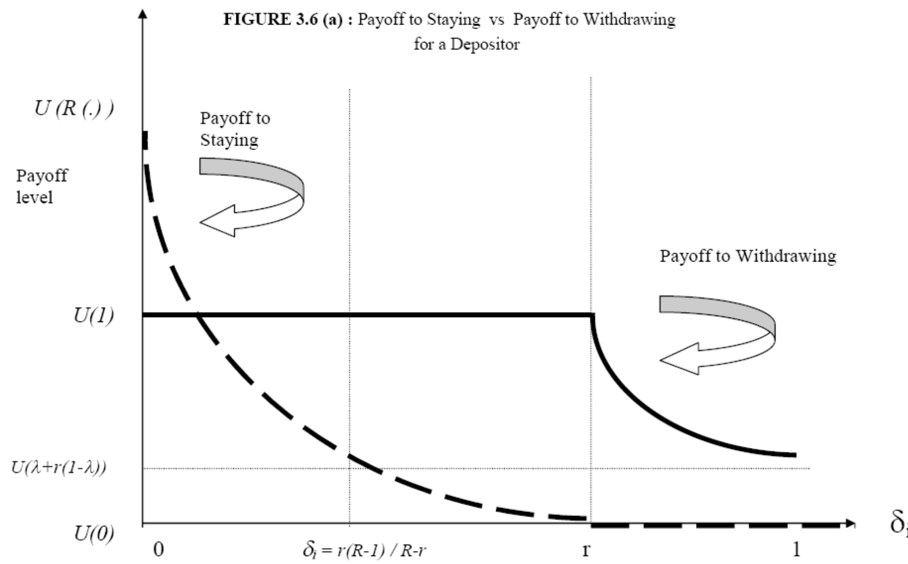


FIGURE 3.6 (a) : Payoff to Staying vs Payoff to Withdrawing for a Depositor

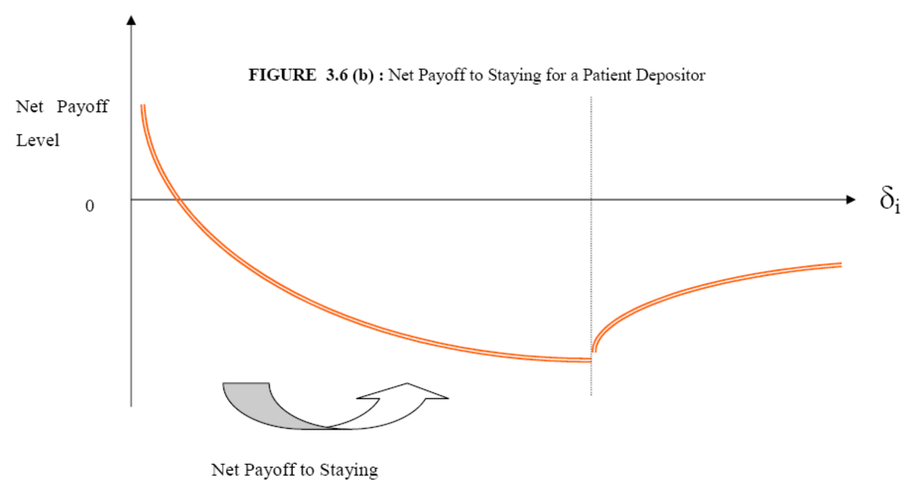


FIGURE 3.6 (b) : Net Payoff to Staying for a Patient Depositor

the time of acting. *From now onwards, we drop the subscript i from all relevant variables (except for θ_i) because the analysis is same for either bank.*

Each patient depositor noisily observes the idiosyncratic fundamental of his bank, θ_i. A depositor's private signal can be viewed as his private heterogeneous information available to him regarding his opinion about the long term viability of the bank's investment project. We motivate the construction of the signal space by focusing on that part of the space that allows for strategic interraction among depositors i.e each agent receives a signal s that forms part of interval $[s_L, s_U]$, where s_L denotes the lower bound of the signal space and s_U denotes the upper bound[13]. The point behind such formalisation is that it enables us differentiate between the segment of idiosyncratic fundamental in which the behaviour of depositors can be anticipated for sure and the part that allows for strategic interraction between depositors.

Each agent's signal s is assumed to be independent and identically distributed, conditional on θ_i. Thus, s denotes the type of the depositor . To keep the analysis simple bearing in mind the above features, for bank i, we shall model the relationship between s and θ_i as follows: $s = \theta_i + \varepsilon$ where ε denotes the noise technology. We assume that the noise technology is common knowledge and is uniformly distributed on a closed interval $[-\varepsilon, +\varepsilon]$. Each element of ε is independent of θ_i and of other disturbance elements. Let s_L denote the signal that corresponds to $u^G - \varepsilon$ and let s_U correspond to $u^{Bad} + z + \varepsilon$. There exists a tripartite classification of the $s - space$ (i.e the signal space) such that $s \in \{s : s_{untable} \cup s_{\mathrm{mod}\,erate} \cup s_{stable}\}$ where $s_{untable} = \left\{s : 0 \leq s < u^G - \varepsilon\right\}$, $s_{\mathrm{mod}\,erate} = \left\{s : u^G - \varepsilon \leq s \leq u^{Bad} + z + \varepsilon\right\}$, $s_{stable} = \left\{u^{Bad} + z + \varepsilon < s \leq 1\right\}$.

The interpretation of that tripartite classification is self-explanatory: $s_{untable} =$

[13]Formally, let ξ denote the set of all "lower bound" θ, where $\xi = \left\{u^G, u^{Bad}\right\}$. Since $u^{Bad} > u^G$, the greatest lower bound is the realisation of θ that corresponds to state u^G. Similarly, we define $\xi\prime$ as the set of "upper bound" θ, where $\xi\prime = \{u^G + z,\, u^{Bad} + z\}$. Since $u^{Bad} + z > u^G + z$, the greatest upper bound is the realisation of θ relating to $u^{Bad} + z$.

$\{s : 0 \leq s < u^G - \varepsilon\}$ denotes the (unstable) region in which the depositors of a given bank always withdraw, no matter what others of the same bank do; $s_{stable} = \{u^{Bad} + z + \varepsilon < s \leq 1\}$ denotes the (stable) region in which the depositors always stays; $s_{\text{mod}\, erate} = \{s : u^G - \varepsilon \leq s \leq u^{Bad} + z + \varepsilon\}$ denotes the middle segment which typifies that the bank is sound but is vulnerable to a large attack that triggers a regime change. Because of uniform distribution of θ_i and of ε, it turns out that the an idiosyncratic fundamental in the range $0 \leq \theta_i < u^G - 2\varepsilon$, is a guarantee that all agents receive signals in the $s_{untable} = \{s : 0 \leq s < u^G - \varepsilon\}$ zone. Similarly, a fundamental in the range $u^{Bad} + z + 2\varepsilon < \theta_i \leq 1$, is a guarantee that all agents receive signals in the $s_{stable} = \{u^{Bad} + z + \varepsilon < s \leq 1\}$ zone. We make the following remarks[14] about the choice of s in the signal range:

Remark 3.1: (**No-Dominance signal segment**) *Attention will be restricted to the segment of the signal space in which there is strategic interraction (i.e Dominance is ruled out). This means that s lies in interval $[s_L, s_U]$, where $s_L \equiv u^G - \varepsilon$ and $s_U \equiv u^{Bad} + z + \varepsilon$.*

Remark 3.2: (**Uniformity of Prior and Posterior distribution**) *While the prior distribution of the idiosyncratic fundamental is common knowledge and follows the uniform distribution law, the posterior distribution of the idiosyncratic fundamental, through specific restrictions on the degree of precision of the signals, will also follow the uniform distribution law. The necessary and sufficient condition for that restriction on the noise structure is: $2\varepsilon < u^G$.*

Proof: In Technical Appendix (section A.2).

It is important to note that, in our framework, it is impossible for depositors of a given bank to meet, share their information and learn the true value of θ_i through the Law of Large Numbers (LLN).

[14] These follow from Morris and Shin (1998). We adapt them in the context of our model here

3.5.2 Public Information Structure

Define $\Gamma_{i,t=1}$, $i = \{A, B\}$, as the stage game for withdrawal decision by patient depositors of bank i in period $t = 1$. For patient depositors acting in $\Gamma_{B,t=1}$, in addition to their private signal s_B about their bank's idiosyncratic fundamental θ_B, they observe a (non-empty) set of (historical) events that have taken place in $\Gamma_{A,t=1}$. Let Ω^A be the space of events in bank A[15]. The event $\Omega_A = \{S^A, F^A\} \equiv$ {Success of Bank A, Failure of Bank A} is commonly observed by all depositors who act in $\Gamma_{B,t=1}$ and forms part of their informational endowment. Some qualitative features of the public signal include:

[1] The public event in the first bank can be used as a *learning mechanism* by depositors in $\Gamma_{B,t=1}$to update beliefs about the state of the common macroeconomic fundamental. Since the game structure is assumed not to be common knowledge, depositors in $\Gamma_{B,t=1}$are assumed not to know whether those who act in $\Gamma_{A,t=1}$ observe the realisation of the common macroeconomic fundamental. This informational deficiency creates a natural leeway for making stochastic inferences on the posterior state of the macroeconomic fundamental.

[2] All depositors in $\Gamma_{B,t=1}$observe the public signal independently of each other. The public signal is identical for all depositors in bank B and confers the same qualitative information about the event that has taken place in bank A.

[3] The event space, $\Omega^A = \{S^A, F^A\}$, provides information to those depositors playing in $\Gamma_{B,t=1}$ of the actions of depositors in $\Gamma_{A,t=1}$. Since events in bank A are triggered essentially as a coordinated response by depositors who act in $\Gamma_{A,t=1}$, these events are informative of the (coordinated) actions of depositors in $\Gamma_{A,t=1}$. Hence events communicate (coordinated) actions in our set-up.

[15]Technically, Ω^A comprises a (non-empty)set of k events, where $k = \{1, ..., n\}$, with each event denoted as Φ_k. We assume that the folllowing properties hold: $P(\cup_{k=1}^{n}\Phi_k) = 1$ and $P(\cap_{k=1}^{n}\Phi_k) = 0$ i.e the events are *mutually exclusive* and *collectively exhaustive*. In our setting, the events spanning $\Gamma_{A,t=1}$ can be either a Success (S^A) or Failure (F^A). Thus, $k = 2$ and $\Omega^A = \{\Phi_1, \Phi_2\}$, with $\Phi_1 = S^A$ and $\Phi_2 = F^A$.

If bank A fails (F^A is observed), then it is clear to successors that all patient depositors in $\Gamma_{A,t=1}$have chosen to withdraw (W) early rather than Stay (S).

Subsequently, the private signals for each depositor in $\Gamma_{A,t=1}$ and $\Gamma_{B,t=1}$ characterise the incompleteness of information *within* each coordination game, $\Gamma_{A,t=1}$ and $\Gamma_{B,t=1}$ respectively. Beliefs that each depositor has about the idiosyncratic fundamental of his own bank are driven essentially by his private signal. Even though events communicate actions of predecessors, they do not say anything about what caused such actions. For depositors playing in $\Gamma_{A,t=1}$, only the prior belief about that fundamental is taken into account (in addition to their private signals) to compute the expected net payoffs of staying. The event in bank A may be driven by realisations of θ_A or by the state of the common fundamental going from one state to another.

θ_A is specific to bank A and is not observed by those playing in $\Gamma_{B,t=1}$. The only other relevant variable that may have caused the event in bank A and that will affect the payoffs of depositors playing in $\Gamma_{B,t=1}$ is the state of the common macroeconomic fundamental. Upon observing Ω^A, depositors in $\Gamma_{B,t=1}$ will use this extra information strategically to form a re-assessement of the probability distribution of the state of the common macroeconomic fundamental. Thus, one of the possible reasons for depositors in $\Gamma_{B,t=1}$ to rationally update their prior beliefs of the state of the common macroeconomic fundamental is that, this fundamental is the only variable that is relevant for bank A and that also affects their payoffs. While our modelling structure achieves the task of keeping payoffs across banks separate, the bayesian reassessment of macroeconomic fundamental priors by depositors of bank B, provides a legitimate informational spillover channel that affects the behaviour of depositors playing in $\Gamma_{B,t=1}$. We assume that all depositors in $\Gamma_{B,t=1}$update their beliefs in the same way.

3.6 Taxonomy of the Dynamic Bayesian Game

Armed with the conceptual pillars we have developed in the previous subsections, we are now ready to provide an illuminating synopsis of the sequential game that is being played between depositors of the 2 banks. Some additional assumptions follow the discussion.

An important part of the sequential game with incomplete information is who determines the first-mover of the game. Since both banks are otherwise completely identical to each other, it makes no difference as to which bank shall move first. In line with good economic theory and not to abuse the literature of sequential move games with incomplete information, we shall be assuming that nature chooses at random and, with equal probability, the first mover of the game. Lets assume that depositors in bank A are chosen to act first[16]. The sequence of events that form part of the dynamic Bayesian game, is depicted next.

[16] Given the features of the payoff structure of each bank and the assumption of complete homogeneity, it does not matter as to which bank's depositors move first. For ease of exposition, we simple label the first-mover bank as bank A and the second-mover bank as bank B. Issues like 'First-Mover Advantages' are not present in our set-up. They could be present, though, in models in which the banks are directly connected to each other through the inter-bank market (in deposits or loans). In this case, regional liquidity shocks would mean that one bank is a debtor and the other bank is a creditor at a given period of time. See Dasgupta (2004) for more.

Period t = 0

[1] Each agent invests in the bank of his region

[2] Each bank chooses its optimal portfolio and invests its depositors' endowment in either a safe-and-liquid technology or risky-and-illiquid technology

[3] Realisations of the idiosyncratic fundamental and of the common macroeconomic fundamental occur (not observed by depositors)

[4] Which group of depositors will be called upon to act first becomes publicly known (say, Bank A)

Period t = 1

[5] Impatient depositors of banks A and B have a dominant strategy of withdrawing early

[6] Each patient depositor in bank A receives noisy information about his bank's idiosyncratic fundamental

[7] Those patient depositors who demand early payment are paid, contingent on there being sufficient cash available to meet withdrawals demands

[8] The event in bank A becomes public knowledge and is commonly observed by depositors of bank B

[9] Each patient depositor in bank B receives a private signal about bank B's idiosyncratic fundamental

[10] Those patient depositors who demand early payment are paid, contingent on there being sufficient cash available to meet withdrawals demands

Period t = 2

[11] Risky-and-illiquid investment technology returns are realised, if not liquidates in period t=1

[12] Those depositors in each bank who have chosen to stay rather than withdraw from their banks get their due back

With homogeneity in the structural features of banks and in their operating environment, the only parameter that links the payoffs for each stage game is change in perceptions of the common macroeconomic fundamental. By assuming that payoffs of depositors across banks are unrelated, our setup enables us to focus on how the flow of information affects the dynamics of coordination in each bank, based on the changes in the perceptions about the common macroeconomic fundamental. We depart from Allen and Gale (2000) and Dasgupta (2004) by abstracting any other form of direct linkages represented, say, by an overlapping network of financial contracts in the payoff structure of banks. In a richer model with regional liquidity shocks and the existence of some form of contingency plan provided by the interbank market, such form of direct link in the payoff structure would have existed.

3.7 Conclusion

The purpose of this chapter was to introduce the formal environment for our banking setup. We began our analysis by highlighting our mission statement for this chapter and the subsequent two. Our aim is to develop a theoretical model that enables us to distinguish (in probabilistic terms) between the two related concepts of banking contagion and correlation in a given banking panic transmission. For banks that have common exposure to a risky asset, mutiple bank failures will carry symptons of both elements and they occur simultaneously. However, to our knowledge, the existing literature fails to provide a robust framework that enables researchers to distil between contagion and correlation in one setting and, crucially to distinguish between the two as equilibrium phenomena. Our contribution is meant to bridge that lacuna.

Our setup differs from the existing literature on several fronts: In addition to extending the Diamond and Dybvig (1983) framework to embrace two banks, we allow an interraction of three factors to define the novelty of our environment: [1] a sequential move game among depositors of both banks, [2] an interplay between private and public signals as informational attributes of depositors and [3] the global game methodology as way of circumventing the problem of equilibria multiplicity. We will build on this framework in **chapters 4** and **5.** In **chapter 4**, we will focus on equilibrium characterisation of our dynamic Bayesian structure and **chapter 5** will document the results of our findings. Please turn over for an illustration of (supplementary) Figures 3.4 (b), (c) and (d).

FIGURE 3.4 (b): Common Macroeconomic Fundamental going moving from Good (G) to Bad (Bad) State

Assume: $\delta_i = 1$

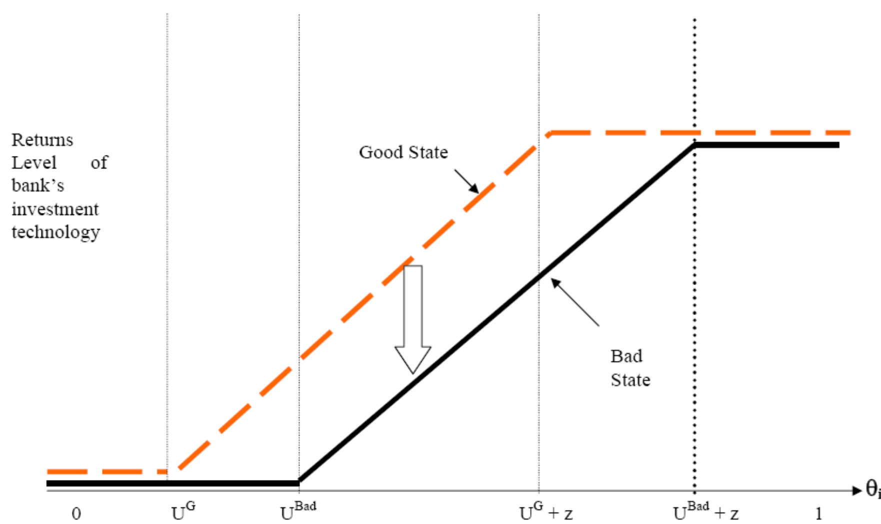


FIGURE 3.4 (c): An increase in Parameter z: Impact on Returns Structure

Assuming: [1] State of Common Macroeconomic Fundamental: j
: [2] z increases to new level z'

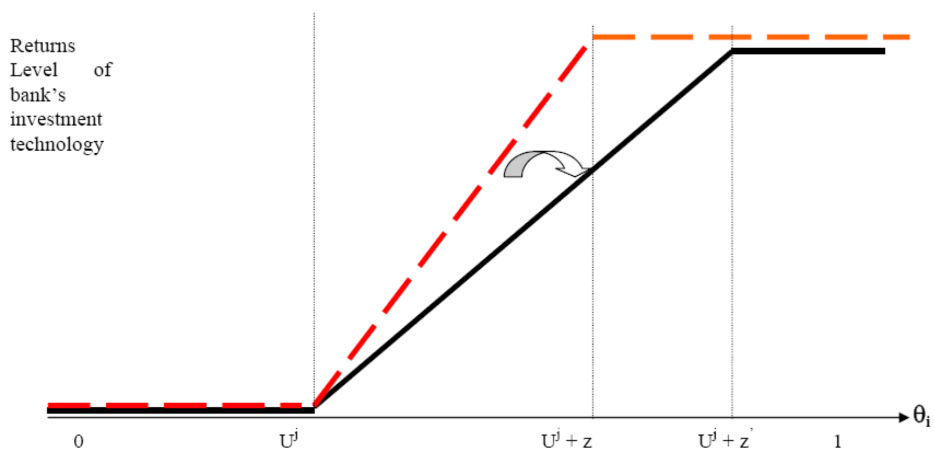
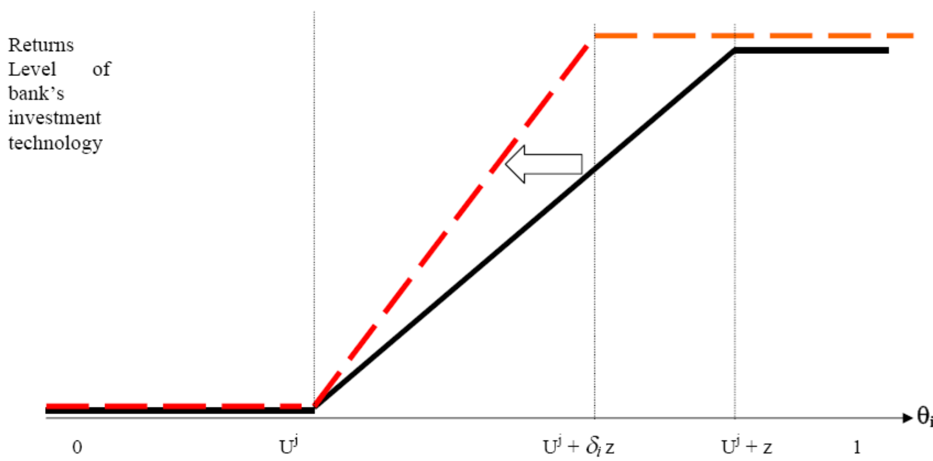


FIGURE 3.4 (d): A change in Parameter δ_i : Impact on Returns Structure

Assuming: [1] State of Common Macroeconomic Fundamental: j
: [2] A decrease in parameter δ_i from 1 to a new level δ_i, where $0<\delta_i<1$



Chapter 4

Banking Equilibrium

4.1 Introduction

This chapter builds on **chapter 3** and outlines the equilibrium characterisation of the dynamic Bayesian game between depositors of bank A and bank B.

As a reminder, our banking environment consists of three periods, two banks (banks A and B) and a cohort of depositors from each bank being called upon to take a decision as to whether to stay or withdraw their money from their respective banks in the interim period. The banks have common investments in risky assets (whose returns are affected by stochastic idiosyncratic fundamentals which follow a uniform distribution) and are perceived to be connected positively to some common macroeconomic fundamental. The exact state of the macroeconomic fundamental is unknown but it follows a known Bernoulli probability distribution function. Depositors of bank A act first (i.e take a decision as to whether to stay or withdraw.) The event in bank A becomes public information. Then, depositors in bank B are called upon to act. We assume that all depositors receive a noisy private signal of their own bank's idiosyncratic fundamental.

The novelty of the chapter is that it establishes the Perfect Bayesian Equilibrium (PBE) for two cohorts of depositors rather than for individual agents (which is the general textbook case) and, most importantly, establishes a connection between the PBE concept and the trigger equilibrium concept. A new contribution that has, hitherto, not been discussed in the pure theoretical literature, is the link between these two equilibria concept. Unlike Dasgupta (2004) and Goldstein and Pauzner (2005) who, both, establish the existence of a trigger equilibrium in a static game setting with incomplete information, our focus is essentially dynamic: we show that along the dynamic equilibrium pathway prescribed by the PBE as a general rule, a trigger equilibrium can be rationalised as a PBE. This novelty enables us to focus on trigger equilibria throughout since we will be in position in **chapter 5** to characterise events in probability terms.

This chapter is organised as follows: **Section 4.2.1** describes the strategy profiles for each depositor in both banks. We assume that each depositor follows a switching strategy in his private signal space – he stays on his bank if his signal is above a threshold signal and withdraws otherwise. For those acting in bank A, the informational attributes that define their type space is their private signals and the prior probability of the state of the common macroeconomic fundamental. For those acting in bank B, their type is defined by their private signals, the public signal about the event that had taken place in bank A (i.e whether it has succeeded or failed) and, most importantly, the posterior probability of the state of the common macroeconomic fundamental upon observing the event in bank A. For depositors of bank B, the mechanics of updating the statistical assessment of the state of the common macroeconomic fundamental from prior state to posterior state, is undertaken using Bayesian updating process. Before describing the learning mechanism that is embodied in the Bayesian reassessment process, **section 4.2.2** derives general rules for the best-response correspondences that underpin the PBE of the dynamic game between cohorts of depositors of bank A and those depositors of bank B. We show that, if the event in bank A is used for Bayesian updating about the state of the common macroeconomic fundamental, the PBE can be described as a trigger equilibrium in depositors' strategies. The first section of **section 4.2.3** shows another important theoretical contribution of our paradigm: we show that, for depositors of each bank, such a trigger equilibrium, in fact, exists. We are able to establish the existence of a trigger equilibrium in each bank's idiosyncratic fundamental (which is dependent on the common macroeconomic fundamental state) as a PBE.

The main anatomical feature of our dynamic Bayesian game consists of two coordination games (one for depositors of bank A and one for those of bank B), with each coordination game being linked strategically by the Bayesian mechanics tool that constitutes the informational spillover channel. Given this structure, the private signals for depositors of either bank, constitute the coordination device for depositors' behaviour and hence, affect the determination of depositors' net payoff to staying. This payoff function determines the location of the equilibrium trigger threshold for either bank. The public event in bank A, will affect the posterior beliefs of depositors of bank B about the state of the common macroeconomic fundamental. Thus, for bank B, the location of the equilibrium trigger threshold is affected by the Bayesian reassessment of the common macroeconomic fundamental. **Section 4.2.3** describes this process in details and describes how this Bayesian reassessment constitutes the informational spillover channel in our model. Upon observing a failure of bank A, for instance, depositors infer that the probability that the state of the common fundamental is bad, is higher than what would have been suggested by the prior probability of that state. This affects the depositors' expected net payoff to staying and biases their decision towards withdrawing.

This trigger equilibrium defines the probability of a bank succeeding or failing in the bank's performance space. An important result of our approach is that, for depositors of bank B, the mechanics of Bayesian updating has a non trivial impact on the probability of bank successes and failures, by affecting the location of the trigger equilibrium. The material embodied in this chapter will be taken further ahead in **chapter 5**, to characterise the concepts of financial contagion and correlation.

4.2 Equilibrium Characterisation

We start this sub-section by allowing the strategy profiles in the coordination games, $\Gamma_{A,t=1}$and $\Gamma_{B,t=1}$ to take a switching form; the expected net payoff structure to staying for the 'marginal depositor' in each bank is then explicated. The Perfect Bayesian Equilibrium (PBE) is defined and formally related to our model. One interesting result is that the PBE satisfies the trigger equilibrium. That simplifies the analysis greatly and enables us to focus on trigger equilibrium when it comes to explicating the model results.

4.2.1 Strategy Profiles

First-mover depositors (i.e depositors in bank A) do not observe a history of past events, when they are called upon (randomly by nature) to move in $\Gamma_{A,t=1}$. Their informational endowment when they act in $\Gamma_{A,t=1}$,thus consists of their private signal (which denotes their type), the *prior probability distribution* of the state of the macroeconomic fundamental and the history set depicting the set of action profiles by predecessors, which in this case, is equal to the null set. Formally, let $\Theta^A_{t=1}$denote the informational endowment of a typical patient depositor in bank A at $\Gamma_{A,t=1}$. Then, conditional on playing in $\Gamma_{A,t=1}$, $\Theta^A_{t=1} = \{s_A, \zeta, H^{\Gamma_{A,t=1}}\}$[1]. So, for each depositor acting in $\Gamma_{A,t=1}$,the equilibrium strategy profile takes the following mapping: $\sigma : \Theta^A_{t=1} \to a \in A = \{W, S\}$. We will be focusing on *switching strategies* throughout the analysis, which we define as follows:

Definition 4.1 (**Switching Strategy for depositors in** $\Gamma_{A,t=1}$ **)** *A depositor of bank A, when acting in* $\Gamma_{A,t=1}$, *is said to be following a switching strategy*

[1] where s_A denotes the private signal of the typical depositor about θ_A (with all the associated features of the private signal as discussed before), ζ is the prior probability distribution over the common macroeconomic states and $H^{\Gamma_{A,t=1}} = \{\phi\}$ denotes the history of actions for depositors in $\Gamma_{A,t=1}$

if he changes his action profile, depending on whether the private signal he receives is below or above a signal threshold, s^*. If $\sigma : \Theta^A_{t=1} \rightarrow a \in A = \{W, S\}$ holds where $\Theta^A_{t=1} = \{s_{A,}\ \zeta,\ H^{\Gamma_{A,t=1}}\}$, then a switching strategy will take the following form:

$$\sigma(\mathit{\Theta}^A_{t=1}) = \left\{ \begin{array}{ll} W & if\ s \leq s^* \\ S & if\ s > s^* \end{array} \right\}$$

As mentioned in the last section, depositors playing in $\Gamma_{B,t=1}$ will form a re-assessement of the probability distribution of the state of the common macroeconomic fundamental . The *updated (posterior) probability distribution* spanning the state of the common macroeconomic fundamental is denoted as $\zeta\prime$. Thus, formally, if $\Theta^B_{t=1}$denotes the informational endowment of depositors who move in $\Gamma_{B,t=1}$, then $\Theta^B_{t=1} = \{s_B, \zeta\prime, H^{\Gamma_{B,t=1}}\}$ where s_B denotes the private signal on θ_B, $\zeta\prime$ is the (posterior) re-appraisal of the prior probabilities of the states of the common macroeconomic fundamental and $H^{\Gamma_{B,t=1}}$ is the history set which contains the events that occurred in bank A. In a similar line of reasoning as for depositors in $\Gamma_{A,t=1}$, we argue that strategies for each depositor acting in $\Gamma_{B,t=1}$ take the following mapping: $\sigma : \Theta^B_{t=1} \rightarrow a \in A = \{W, S\}$, and that all depositors follow switching strategies around some signal threshold. The trigger strategy for those acting in $\Gamma_{B,t=1}$ is defined in an analogous way to that of depositors playing in $\Gamma_{A,t=1}$, except that here, the informational attributes of depositors are augmented in this case in order to account for updated re-assessment of common probability distributions and inclusion of a non-empty historical set.

Definition 4.2 *(***Switching Strategy for depositors in** $\Gamma_{B,t=1}$*) A depositor of bank B, when acting in* $\Gamma_{B,t=1}$, *is said to follow a trigger strategy with the following mapping,* $\sigma : \Theta^B_{t=1} \rightarrow a \in A = \{W, S\}$, *if his behaviour is defined as* *follows:* $$\sigma(\Theta^B_{t=1}) = \left\{ \begin{array}{lll} W & if & (\ \Omega^A = \{F^A\}) \cap (\ s \leq s^*) \\ S & if & (\ \Omega^A = \{S^A\}) \cap \ (\ s > s^*) \\ S \text{ or } W & if & \left\{ \begin{array}{c} either \ \big((\ \Omega^A = \{S^A\}) \cap \ (\ s \leq s^*)\big) \\ or \ \big((\ \Omega^A = \{F^A\}) \cap (\ s > s^*)\big) \end{array} \right\} \end{array} \right\}$$

where $\Theta^B_{t=1} = \{s_B, \zeta\prime, H^{\Gamma_{B,t=1}}\}$

This definition of switching strategy for depositors in $\Gamma_{B,t=1}$ provides a straightforward characterisation of the behaviour of these depositors. Depositors stay if they observe the public information of the success of bank A (i.e $\Omega^A = \{S^A\}$) and their private signals exceed a certain threshold in their private information space (i.e $s > s^*$). With the reverse ordering, they will choose to withdraw. The behaviour of depositors in $\Gamma_{B,t=1}$, will be indeterminate otherwise. One of such possibility is the occurrence of, say, event $\big((\ \Omega^A = \{F^A\}) \cap (\ s > s^*)\big)$. Here, observing the failure of bank A is likely to bias the depositor's decision towards withdrawing but a strong private signal is likely to have the opposite effect. In this case, the decision as to whether to stay or withdraw, will depend on comparison of the expected payoff to staying with the payoff to withdrawing.

4.2.2 Perfect Bayesian Equilibrium (PBE) of Game Between $\Gamma_{A,t=1}$ And $\Gamma_{B,t=1}$

Definition 4.3 (**Perfect Bayesian Equilibrium)** *A Perfect Bayesian Equilibrium (PBE) in the game between $\Gamma_{A,t=1}$ and $\Gamma_{B,t=1}$, is an assessment of strategy profiles for depositors of each group $\{\sigma : \Theta^A_{t=1} \to a \in A = \{W, S\}$ in $\Gamma_{A,t=1}$ and $\sigma : \Theta^B_{t=1} \to a \in A = \{W, S\}$ in $\Gamma_{B,t=1}\}$ and a set of beliefs $\{\zeta, \zeta\prime\}$ where ζ is the set of prior beliefs about the common fundamental and ζ' is the posterior belief such that:*

[**1**] *Given his beliefs about the common fundamental (either ζ or $\zeta\prime$) and after every possible history $H^{\Gamma_i, t=1}$, $i = \{A, B\}$, each depositor's strategy is rational for each of his signals (i.e is a best-response to any possible moves by*

all depositors of the same bank) given that these other depositors also play this maximising game.

[2] *With the history of past events occuring with positive probability, then the beliefs system $\{\zeta, \zeta\prime\}$ should be optimal given the strategies of depositors of banks A and B, namely $\sigma(\Theta^{A}_{t=1})$ and $\sigma(\Theta^{B}_{t=1})$ respectively. This means that ζ' is derived from ζ using Bayes Rule.*

The above formal definition of the PBE in the game between $\Gamma_{A,t=1}$and $\Gamma_{B,t=1}$translates into the following criteria / requirements:

Criterion 4.1: (Beliefs Formation) *Each depositor with the move has some belief about the state of the common macroeconomic fundamental (represented by some probability distribution)*

Denote $\mu(u \mid \Theta^{B}_{t=1})$ as the process of of updating beliefs about the common macroeconomic fundamental from its prior state ζ to the posterior state $\zeta\prime$ for each depositor in $\Gamma_{B,t=1}$. For depositors in $\Gamma_{A,t=1}$, there is no such updating process. Since depositors in $\Gamma_{A,t=1}$ move first and their information set, $\Theta^{A}_{t=1}$contains an empty historical set, it is not hard to realise that $\mu(u \mid \Theta^{A}_{t=1})$ is the same as the prior probability over states denoted as ζ .

Criterion 4.2: (Sequential Rationality) *Given his beliefs about the common macroeconomic fundamental (as per criterion 1) in his information set, each depositor's strategy must maximise his payoffs, given that other depositors of the same bank will also play this optimising game.*

This idea of rationality needs more elaboration, given the complex nature of our payoff function and given that, unlike most sequential move games with incomplete information, we do not have one individual moving at a time, but a continuum of individuals doing so.

(The following analysis is valid for depositors of either bank, except where otherwise stated). Each depositor playing in $\Gamma_{i,t=1}$ faces a uniform posterior belief over θ_i, conditional on observing his private signal s. Our former assumptions about the signal space allow us to focus on that segment of the space that allows for strategic interraction between depositors and to model the posterior distribution of θ_i , conditional on observing signal s , as $\theta \mid s \sim Uniform[s-\varepsilon, s+\varepsilon]$, $\varepsilon \leq s \leq 1-\varepsilon$. Assuming that all other depositors play by the switching strategy as highlighted earlier, then the proportion of early withdrawals can be modelled as:

$$\delta[\theta, s^*] = \left\{ \begin{array}{ll} 1 & \theta < s^* - \varepsilon \\ \frac{1}{2} + \frac{(s^*-\theta)}{2\varepsilon} & s^* - \varepsilon \leq \ \theta \leq s^* + \varepsilon \\ 0 & \theta > s^* + \varepsilon \end{array} \right\}$$

In particular, the 'net payoff to staying' for depositor in $\Gamma_{i,t=1}$ can be represented as: $\Pi(\theta, s) = \displaystyle\int_{s-\varepsilon}^{s+\varepsilon} \pi(\theta, \delta[\theta, s])\ d\theta$, where $\pi(\theta, \delta[\theta, s])$ relates to $U\left[\frac{\left\{(1-\lambda)-\frac{\delta(1-\lambda)}{r}\right\}\tilde{R}]}{(1-\lambda)(1-\delta)}\right] - U(1)$ if $\delta \leq r$ and $U(0) - U\left[\frac{\lambda+r(1-\lambda)}{\lambda+\delta(1-\lambda)}\right]$ if $\delta > r$. First, we move with the characterisation of the Perfect Bayesian Equilibrium (PBE) of the dynamic game between $\Gamma_{A,t=1}$ and $\Gamma_{B,t=1}$,by starting

with the decision problem of depositor in $\Gamma_{B,t=1}$. For the marginal depositor in bank B, the payoff structure denoted as $\Pi(\theta, s^*) = \displaystyle\int_{s^*-\varepsilon}^{s^*+\varepsilon} \pi(\theta, \delta(s^*, \theta))\ d\theta$ and the depositor observes the actions of those in bank A. He adjusts his beliefs of the probability of the common macroeconomic fundamental from ζ to $\zeta\prime$. His expected utility to staying as opposed to withdrawing will depend on this posterior belief $\zeta\prime$ of the common fundamental, his posterior belief of the idiosyncratic fundamental conditional on observing his private signal s and the strategy of successors in the continuation game. Since the withdrawal game ends after $\Gamma_{B,t=1}$, there are no successors in this game. Formally, the expected utility to staying as opposed to withdrawing is modelled as:

$$EU[s^*, \zeta\prime] = P\int_{s^*}^{s^*+\varepsilon} \pi(\theta, \delta(s^*, \theta))d\theta + (1-P)\int_{s^*-\varepsilon}^{s^*} \pi(\theta, \delta(s^*, \theta))d\theta$$

where ζ' is the posterior belief of the common macroeconomic fundamental based on the event in bank A, P denotes some probability that bank B succeeds, given the strategies pursued by depositors in bank A and as before,

$\int_{s^*}^{s^*+\varepsilon} \pi(\theta, \delta(s^*, \theta))\ d\theta$ denotes the positive part of the net payoff to staying and $\int_{s^*-\varepsilon}^{s^*} \pi(\theta, \delta(s^*, \theta))\ d\theta$ denotes the negative part. Since $\int_{s^*}^{s^*+\varepsilon} \pi(\theta, \delta(s^*, \theta))$ $d\theta = -\int_{s^*-\varepsilon}^{s^*} \pi(\theta, \delta(s^*, \theta))\ d\theta$,then $EU[s, \zeta\prime]$ can be re-written as :

$$EU[s, \zeta\prime] = [2P - 1] \int_{s^*}^{s^*+\varepsilon} \pi(\theta, \delta(s^*, \theta)) d\theta$$

The expression we give for $EU[s, \zeta\prime]$ is very intuitive. The expected utility to staying for any depositor playing in $\Gamma_{B,t=1}$ depends on the actions of other depositors in $\Gamma_{B,t=1}$. The associated payoffs $\int_{s^*}^{s^*+\varepsilon} \pi(\theta, \delta(s^*, \theta))\ d\theta$ and $\int_{s^*-\varepsilon}^{s^*} \pi(\theta, \delta(s^*, \theta))\ d\theta$, respectively depict the ex-post payoffs to the depositor in $\Gamma_{B,t=1}$ when all depositors stay and withdraw respectively, given their switching strategy around s^*. Thus, one can see that $\delta(s^*, \theta)$ affects the probability of success or failure in bank B and also the expected net payoff to staying for an individual depositor: $\Pi(s^*, \theta)\ \ (= \int_{s^*-\varepsilon}^{s^*+\varepsilon} \pi(\theta, \delta[\theta, s^*])\ d\theta)$. For example, when $\delta(s^*, \theta)$ is sufficiently high, the expected net payoff to staying for a marginal depositor, given that all other depositors are playing a switching strategy around s^*, will be given by $\int_{s^*-\varepsilon}^{s^*} \pi(\theta, \delta(s^*, \theta))\ d\theta\ (< 0)$. Thus, more weight is given to the negative element of the expected net payoff. Conversely, for low proportion of early withdrawals, $\delta(s^*, \theta)$, more weight is given to the positive element of the expected net payoff: to staying is positive i.e $\int_{s^*}^{s^*+\varepsilon} \pi(\theta, \delta(s^*, \theta)) d\theta > 0$. To know exactly which value $\delta(s^*, \theta)$ will take, depends on the optimising strategy of depositors of bank B. Each depositor in $\Gamma_{B,t=1}$ who receives some signal s chooses an action that maximises his expected utility, given the optimising actions of other depositors in the same bank. Taking into account the beliefs updating process as well as the best reponse of other depositors, the best-response function for each depositor in $\Gamma_{B,t=1}$ who receives some signal s, can be expressed as follows:

$\Psi^B(.) = \max_{a\, \in\, A} [2P - 1] \int_{s}^{s+\varepsilon} \pi(\theta, \delta(s^*, \theta))\ \mu(u \mid \Theta^B_{t=1}) d\theta$ where the net payoff function has been augmented to allow for posterior beliefs about the state of the common fundamental.

For each depositor in $\Gamma_{A,t=1}$ who receives a signal s^*, the payoff structure can be expressed as $\Pi(\theta, s^*) = \int_{s^*-\varepsilon}^{s^*+\varepsilon} \pi(\theta, \delta(s^*, \theta))\ d\theta$ assuming that all other depositors in bank A follow a switching strategy around s^*. In a way analoguous to the analysis carried out for depositors in $\Gamma_{B,t=1}$, we define the best response function for those in $\Gamma_{A,t=1}$ as:

$\Psi^A(.) = \max_{a\ \in\ A}[2P - 1]\int_{s}^{s+\varepsilon} \pi(\theta, \delta(s^*, \theta))\ \mu(u \mid \Theta^A_{t=1})d\theta$ where the net payoff function has been augmented to allow for prior beliefs about the state of the common fundamental. (As argued before, since the history set is nil, $\mu(u \mid \Theta^A_{t=1})$ is the same as prior beliefs about the state of the common fundamental for depositors playing in $\Gamma_{A,t=1}$.

Criterion 4.3: (Bayesian Updating Process) *The beliefs updating process by depositors of bank B from the prior state of the common macroeconomic fundamental to the posterior state is undertaken using Bayesian updating.*

The idea is that while depositors of bank A have some prior beliefs about the state of the common macroeconomic fundamental, depositors in bank B use the public information about bank A to update their beliefs about the state of the common fundamental. As per criterion 2, they use this posterior belief to compute their expected payoffs. We focus on the exact mechanics of the updating process in the next subsection. For the moment, it just suffices to believe that, with no information set being off the equilibrium path given the equilibrium strategies of the game, any updating process that conforms with Bayes rule will still keep us along the trajectory pathway prescribed by the Perfect Bayesian Equilibrium concept.

We next want to show that all equilibrium profiles that satisfy the PBE concept must also be a trigger equilibrium . This will enable us simplify the analysis of the dynamic equilibrium pathway considerably and to focus attention on trigger equilibria throughout the whole experiment.

Proposition 4.1: *If the event in Bank A is used for Bayesian updating only, then the Perfect Bayesian Equilibrium (PBE) of the dynamic game between* $\Gamma_{A,t=1}$ *and* $\Gamma_{B,t=1}$ *can be represented as a trigger equilibrium.*

Proof: In Technical Appendix at end of Thesis (Section A.3).

4.2.3 Characterisation of Trigger Equilibrium

We have shown in the previous section that a PBE of the game between $\Gamma_{A,t=1}$ and $\Gamma_{B,t=1}$ can be represented as a trigger equilibrium. In this section, we show that such a trigger equilibrium actually exists and we explore its properties in more details.

Proposition 4.2(a): (**Existence of a Trigger Equilibrium**) *In each depositor's game, there exists a threshold* s^* *such that he withdraws if* $s \leq s^*$ *and stays if* $s > s^*$

Proof: In Technical Appendix at end of Thesis (Section A.3).

Put simply, the expected net payoff to staying for the marginal depositor who receives a signal of s^* (assuming that all depositors follow the trigger strategy) is given by $\Pi(s^*, \theta) = \int_{s^*-\varepsilon}^{s^*+\varepsilon} \pi(\theta, \delta[\theta, s^*]) \; d\theta = 0$ (where $\pi(\theta, \delta(\theta, s^*))$ is defined in the proof of proposition 4.2(a)). Let the expected net payoff to staying for any depositor who receives some signal s be given by: $\Pi(s, \theta) = \int_{s-\varepsilon}^{s+\varepsilon} \pi(\theta, \delta[\theta, s^*]) \; d\theta$. We have shown in proposition 2(a) that, by the assumption of continuity of the net payoff structure in s^*, when $s \leq s^*$, $\Pi(s, \theta) < \Pi(s^*, \theta) = 0$. The intuition is that when we integrate the payoff function over the $[s - \varepsilon, \; s + \varepsilon]$ range, we add more to the negative element of the payoff and substract a significant part of the positive element of the payoff. Thus, when $s \leq s^*$, the overall net payoff to staying is negative i.e depositors will choose to withdraw rather than stay. Similarly, when $s > s^*$, $\Pi(s, \theta) > \Pi(s^*, \theta) = 0$. A similar logic will show that in this case, integrating the payoff function over

$[s-\varepsilon,\ s+\varepsilon]$ range will mean adding more to the positive element and substracting the negative element of the payoff. When $s > s^*$,the overall net payoff to staying is positive i.e depositors will choose to stay rather than withdraw. This leads us to another important result which we relate to parameters of the model:

Proposition 4.2(b): (**Uniqueness of** s^*) *If s^* exists, then it is unique.*
Proof: From proposition 4.2(a).

Following from propositions 4.2(a) and 4.2(b), it follows that depositors of either bank stay if $s > s^*$ and withdraw if $s \leq s^*$. The above derivations did not specifically explicate how θ^* varies with structural changes in parameters that characterise the returns structure of the illiquid-and-risky technology. We next turn to the existence of θ^* and extol on its main qualitative feature.

Proposition 4.3: (**Existence and Features of** θ^*) Following *propositions 4.2(a) and 4.2(b), there exists a threshold θ^*in each bank, above which the bank succeeds and below which the bank fails. In addition, for either bank, the location of θ^* has the property that : $\theta^*(u^{Bad}) > \theta^*(u^G)$ with $u^{Bad} > u^G$.*
Proof: In Technical Appendix at end of Thesis (Section A.3).

The derivation of the unique threshold for each bank can also be found in other models in the literature. Dasgupta(2004) obtains similar results, albeit with a more complex payoff structure. The existence of the overlapping networks structure of financial contracts that tie the banks together (through the interbank market in deposits) can explain contagion as a unique phenomenon. The failure of bank A means that depositors in $\Gamma_{B,t=1}$,suffer a loss of claims due to them. As a result, their behaviour changes. Other papers in the literature do get the uniqueness result: Goldstein and Pauzner (2005) endogenise the probability of bank runs and relate that probability to the features of the demand-deposit contract. In their paper, as second-best solution, the optimal contract is featured by a trade-off between risk-sharing (efficiency) and the endogeneous probability of bank runs (instability).

Corollary 4.1: (Characterisation of Trigger $\{s_A^*, \theta_A^*(u)\}$ in $\Gamma_{A,t=1}$ and of $\{s_B^*, \theta_B^*(u)\}$in $\Gamma_{B,t=1}$)

Given $\sigma(\Theta_{t=1}^A) \rightarrow a \ \epsilon \ A = \{W, S\}$ and $\sigma(\Theta_{t=1}^B) \rightarrow a \ \epsilon \ A = \{W, S\}$ for depositors in $\Gamma_{A,t=1}$and in $\Gamma_{B,t=1}$ respectively, we can summarise the algorithm that traces the equilibrium values of $\{s_A^*, \theta_A^*(u)\}$ and of $\{s_B^*, \theta_B^*(u)\}$ as follows:

Algorithm tracing equilibrium values of $s_A^*, \theta_A^*(u), s_B^*, \theta_B^*(u)$:

For depositors in $\Gamma_{A,t=1}$,

$$\sigma(\Theta_{t=1}^A) = \left\{ \begin{array}{ccc} W & \text{if} & s \leq s^* \\ S & \text{if} & s > s^* \end{array} \right\}$$

and $\theta_A^*(u)$ solves

$$\left\{ \begin{array}{c} \Pi_A(\theta, s^*) = 0 \\ \text{and } \delta[\theta, s^*] = \left\{ \begin{array}{ll} 1 & \theta < s^* - \varepsilon \\ \frac{1}{2} + \frac{(s^* - \theta)}{2\varepsilon} & s^* - \varepsilon \leq \ \theta < s^* + \varepsilon \\ 0 & \theta \geq s^* + \varepsilon \end{array} \right\} \end{array} \right\}$$

For depositors in $\Gamma_{B,t=1}$,

$$\sigma(\Theta_{t=1}^B) = \left\{ \begin{array}{lll} W & if & (\ \Omega^A = \{F^A\}) \cap (\ s \leq s^*) \\ S & if & (\ \Omega^A = \{S^A\}) \cap \ (\ s > s^*) \\ S \text{ or } W & if & \left\{ \begin{array}{c} either \ \big((\ \Omega^A = \{S^A\}) \cap \ (\ s < s^*)\big) \\ or \ \big((\ \Omega^A = \{F^A\}) \cap (\ s > s^*))\big) \end{array} \right\} \end{array} \right\}$$

and $\theta_B^*(u)$ solves

$$\left\{ \begin{array}{c} \Pi_B(\theta, s^*) = 0 \\ \text{and } \delta_B[\theta, s^*] = \left\{ \begin{array}{ll} 1 & \theta < s^* - \varepsilon \\ \frac{1}{2} + \frac{(s^* - \theta)}{2\varepsilon} & s^* - \varepsilon \leq \ \theta < s^* + \varepsilon \\ 0 & \theta \geq s^* + \varepsilon \end{array} \right\} \end{array} \right\}$$

We can rationalise the existence of a unique equilibrium in the coordination game facing depositors, with the presence of strategic complementarities in depositors' decisions. The uniqueness result of Carlsson and VanDamme(1993) and Morris and Shin (1998), which was obtained in non-banking models, necessarily relies on the existence of (global) strategic complementarities / supermodularities in the payoff structure. An important difference between existing models of banking in the literature (Dasgupta (2004), Goldstein and Pauzner (2005)) and our model, is that we have supermodularities in the payoff structure of depositors. Banking models in the existing literature, are not characterised by supermodularities in the payoff structure - above some threshold, decisions become strategic substitutes. Nonetheless, the innovative approach of Dasgupta(2004) and of Goldstein and Pauzner (2005) is that they show, through the existence of a single-crossing property in the payoff structure and of an error technology that satisfies the Monotone-Likelihood Ratio Property (MLRP), that a unique result can exist even in the absence of strategic complementarities. We can bypass these technicalities for our proof of the uniqueness result.

4.2.4 Mechanics of Beliefs Updating

The re-assessment of the beliefs mechanism of the state of the common macroeconomic fundamental from the prior distribution to the posterior distribution, was constrained to some general form of Bayesian updating process, without explicit reference to the intrinsic stochastic properties of the updating process. In this section, we will add statistical structure to the updating process, elaborate on the stochastic properties of the resulting informational generating process. The updating process does not focus on depositors' private signals because each depositor in $\Gamma_{i,t=1}$ receives his private signal only once in $\Gamma_{i,t=1}$and there is no evolution of private signals over time. Furthermore, by the assumption that $2\varepsilon \leq \min\ [u^G, 1-u^G-z]$ of remarks 3.1 and 3.2 of the previous chapter, each depositor has a private signal which is of minimal precision.

The updating mechanism concerns only parameter u. The actual realisation of u is not *apriori* known to depositors in $\Gamma_{A,t=1}$ and $\Gamma_{B,t=1}$. But upon observing the public event in bank A, depositors in $\Gamma_{B,t=1}$ have an extra information on the state of the common fundamental u , which we shall dub the *learning* *mechanism.* Since they do not observe what is triggering the event in bank A, they face a *statistical inference* problem. Any revised version of the state u, conditional upon observing the event in bank A, constitutes this learning process.

To keep the model analytically tractable, we shall place a few restrictions on the *apriori* distribution. As a reminder, $P(u^{Bad}) = k$ and $P(u^G) = 1 - k$ and ζ is the space that contains this prior probability distribution. Define the partitioned space events, S_A and F_A as follows: $S_A : \{\theta_A > \theta_A^*(u)\}$ and $F_A : \{\theta_A \leq \theta_A^*(u)\}$. Since θ_A is uniformly distributed on $[0,1]$, it follows that $Prob(\theta_A > \theta_A^*(u)) = 1 - \theta_A^*(u)$ and that $Prob(\theta_A \leq \theta_A^*(u)) = \theta_A^*(u)$. With the property that, $u^{Bad} > u^G$, we know, by proposition 4.3, that $\theta^*(u^{Bad}) > \theta^*(u^G)$. The following conditional probability assessments subsequently hold:

$$\begin{aligned}
\Pr ob(F_A &\mid u = u^{Bad}) = \theta_A^*(u^{Bad}) \\
\Pr ob(F_A &\mid u = u^G) = \theta_A^*(u^G) \\
\Pr ob(S_A &\mid u = u^{Bad}) = 1 - \theta_A^*(u^{Bad}) \\
\Pr ob(S_A &\mid u = u^G) = 1 - \theta_A^*(u^G)
\end{aligned}$$

with $\theta_A^*(u^{Bad}) > \theta_A^*(u^G)$ and $1 - \theta_A^*(u^{Bad}) < 1 - \theta_A^*(u^G)$. In the previous section, we denoted $\mu(u \mid \Theta_{t=1}^B)$ as the process of of updating beliefs about the common macroeconomic fundamental from its prior state ζ to the posterior state $\zeta\prime$ for each depositor in $\Gamma_{B,t=1}$ with informational endowment $\Theta_{t=1}^B$. Here, we add structure to the exact nature of $\mu(u \mid \Theta_{t=1}^B)$. Using Bayesian rule, we have the following revision estimates for depositors in bank B, conditional upon observing an event in bank A:

$\Pr ob(u = u^{Bad} \mid F_A) = \frac{P(F_A|u=u^{Bad})P(u=u^{Bad})}{P(F_A|u=u^{Bad})P(u=u^{Bad})+P(F_A|u=u^G)P(u=u^G)}$
$= \frac{k.\theta_A^*(u^{Bad})}{k.\theta_A^*(u^{Bad})+(1-k)\theta_A^*(u^G)}$

Similarly, $\Pr ob(u = u^{Bad} \mid S_A) = \frac{P(S_A|u=u^{Bad})P(u=u^{Bad})}{P(S_A|u=u^{Bad})P(u=u^{Bad})+P(S_A|u=u^G)P(u=u^G)}$

$= \frac{k.(1-\theta_A^*(u^{Bad}))}{k.(1-\theta_A^*(u^{Bad}))+(1-k)(1-\theta_A^*(u^G))}$

Analoguously, $Prob(u = u^G \mid S_A) = 1 - \Pr ob(u = u^{Bad} \mid S_A)$ $= \frac{(1-k)(1-\theta_A^*(u^G))}{(1-k)(1-\theta_A^*(u^{Bad})) + k(1-\theta_A^*(u^G))}$ and $Prob(u = u^G \mid F_A) = 1 - \Pr ob(u = u^{Bad} \mid F_A) = \frac{(1-k)\theta_A^*(u^G)}{(1-k)\theta_A^*(u^G) + k\theta_A^*(u^{Bad})}$. This yields a proposition:

Proposition 4.4: (Learning Mechanism) *Upon observing the failure of bank A, the probability that the common macroeconomic fundamental was in its bad state is more likely than unconditionally. Thus,* [1] $\Pr ob(u = u^{Bad} \mid F_A) > \Pr ob(u = u^{Bad}) > \Pr ob(u = u^{Bad} \mid S_A)$. *Similarly, conditional on observing the success of bank A, the probability that the common macroeconomic fundamental was in its good state is more likely than unconditionally. Thus,* [2] $\Pr ob(u = u^G \mid S_A) > \Pr ob(u = u^G) > \Pr ob(u = u^G \mid F_A)$.

Proof: In Technical Appendix (Section A.3).

The different possibilities of an event in bank A being associated with an event in bank B can be represented by a set of equations that characterise the probability of the events taking place . If we represent $\{F_A, F_B, S_A, S_B\}$ analoguously to what we have done before in the previous section, then we may represent the probability of a failure in bank A being associated with a failure in bank B as follows: $Pr(F_B \mid F_A) = \Pr(\theta_B \leq \theta_B^*(u) \mid \theta_A \leq \theta_A^*(u))$, where $Pr(F_B \mid F_A)$ denotes the probability of bank B failing, given the observed failure of bank A. This can be represented as follows: $Pr(F_B \mid F_A) = \Pr(F_B \mid \{u = u^{Bad}\} \cap F_A) \Pr(\{u = u^{Bad}\} \mid F_A) + \Pr(F_B \mid \{u = u^G\} \cap F_A) \Pr(\{u = u^G\} \mid F_A)$. Since we know the values of $\Pr(\{u = u^{Bad}\} \mid F_A)$ and $\Pr(\{u = u^G\} \mid F_A)$, we can replace these values in the above expression and get a much simplified version of $Pr(F_B \mid F_A)$ where $Pr(F_B \mid F_A) = \left\{\frac{k\theta_A^*(u^{Bad})\theta_B^*(u^{Bad}) + (1-k)\theta_A^*(u^G)\theta_B^*(u^G)}{k\theta_A^*(u^{Bad}) + (1-k)\theta_A^*(u^G)}\right\}$.

Similarly, $Pr(F_B \mid S_A) = \Pr(\theta_B \leq \theta_B^*(u) \mid \theta_A > \theta_A^*(u))$, where $Pr(F_B \mid S_A)$ denotes the probability that bank B fails, given that it is observed that bank A has survived an attack before. This probability can be expressed as $\Pr(F_B \mid$

$\{u = u^{Bad}\} \cap S_A)$ $\Pr(\{u = u^{Bad}\} \mid S_A)$+ $\Pr(F_B \mid \{u = u^G\} \cap S_A)$ $\Pr(\{u = u^G\} \mid S_A)$. We can it as $Pr(F_B \mid S_A) = \left\{ \frac{k(1-\theta_A^*(u^{Bad}))\theta_B^*(u^{Bad})+(1-k)(1-\theta_A^*(u^G))\theta_B^*(u^G)}{1-k\theta_A^*(u^{Bad})-(1-k)\theta_A^*(u^G)} \right\}$ after appropriate substitutions. . Events $Pr(S_B \mid F_A)$ and $Pr(S_B \mid S_A)$ can be derived analoguously in terms of parameters of our model. The interested reader will find that $Pr(S_B \mid F_A) = 1 - Pr(F_B \mid F_A)$

$= 1 - \left\{ \frac{k\theta_A^*(u^{Bad})\theta_B^*(u^{Bad}) + (1-k)\theta_A^*(u^G)\theta_B^*(u^G)}{k\theta_A^*(u^{Bad}) + (1-k)\theta_A^*(u^G)} \right\}$ and that $Pr(S_B \mid S_A) = 1 - Pr(F_B \mid S_A)$

$= 1 - \left\{ \frac{k(1-\theta_A^*(u^{Bad}))\theta_B^*(u^{Bad})+(1-k)(1-\theta_A^*(u^G))\theta_B^*(u^G)}{1-k\theta_A^*(u^{Bad})-(1-k)\theta_A^*(u^G)} \right\}$. The technical appendix contains a section that summarises all conditional and unconditional probability associated with events in the two banks.

Proposition 4.5: *The posterior estimates of the state of the common macroeconomic fundamental by depositors of bank B retain all mathematical properties of propositions 4.2(a), 4.2(b) and 4.3. Furthermore, observing the failure (success) of bank A pushes the trigger of bank B upwards (downwards), such that* $\theta_B^{F_A}(u) > \theta_B^*(u)$ $\left(\theta_B^{S_A}(u) \leq \theta_B^*(u) \text{ respectively}\right)$. *Thus, bank B now fails for larger (smaller) realisations of its own idiosyncratic fundamentals.*

Proof: In the Technical Appendix (Section A.3).

4.3 Conclusion

In this chapter, we build on the banking environment described in **chapter 3**, and endeavour to characterise the equilibrium of the dynamic Bayesian game between depositors of banks A and B. We define each depositor's strategy as a trigger strategy and build on the PBE in terms of best-response correspondences for depositors in each bank. An interesting finding of our approach, is that the PBE can be described as a trigger equilibrium. We move on to show that this trigger equilibrium threshold does exist in each bank's performance space. An interesting result is on the interplay between the trigger equilibrium threshold and the informational spillover channel that is embodied in the Bayesian updating mechanics for depositors in bank B. We show, through the intermediate value theorem that, while the equilibrium threshold can be derived from the single-crossing property that characterises the net payoff of depositors, the location of that threshold is affected by the belief updating process by depositors of bank B.

This creates a well-defined anatomical structure for the dynamic Bayesian game that we describe in this chapter: we have two coordination games linked by a Bayesian updating mechanics (game represented by depositors of bank A, game represented by depositors of bank B, Bayesian updating process by depositors of bank B.) In each coordination game, the private signals of depositors playing in that game act as coordinating devices for their behaviour and determine the net payoff structure of depositors (hence, having an impact on the determination of the equilibrium threshold). For bank B, the updating process underpinned by Bayesian mechanics, affects the position of the payoff structure for depositors of that bank (hence, having an impact on the location of that equilibrium threshold for bank B). The location of the equilibrium thresholds of banks A and B, is crucial in our analysis since it affects the probability of events in those banks (i.e whether banks succeed or fail).

To our knowledge, characterising the equilibrium pathway of a dynamic Bayesian game with the aforementioned anatomy, is completely new to the literature. Showing the equivalence between PBE and trigger equilibrium concept in such a game, has also not been dealt with in the existing literature of equilibrium characterisation of banking models.

The material embodied in this chapter will be taken further ahead in **chapter 5**, to characterise the concepts of financial contagion and correlation. In **chapter 5**, we document specifically how the mechanics of Bayesian reassessment affect the unconditional payoff function for depositors and, thus, the location of the trigger equilibrium. We will describe the existence of two main states of the world: 'tranquil' state and 'non-tranquil' state. The former state is one of 'autarky' i.e a state in which banks do not 'trade' (depositors of the second bank do not observe the event in the first bank). The payoffs of depositors of either bank are not linked in that state and the equilibrium triggers in each bank are independent of each other. The 'non-tranquil' state is one which the event in the first bank is observed and becomes public knowledge. This creates an avenue for a cross-bank linkage by the Bayesian updating process. Upon observing this event (which may be either a success or a failure), depositors of bank B re-interpret the state of the common macroeconomic fundamental by updating their priors of the state of the common macroeconomic fundamental. The trigger equilibrium of the bank B is adjusted such that it is more likely to suffer from the same fate as the first. Determining which part of that panic transmission is contagion and which part is correlation, is the treatise of **chapter 5**.

Chapter 5

Modelling Banking Contagion

5.1 Introduction

In this chapter, we build on the main paradigms developed in **chapters 3** and **4** and discuss the main findings of our results. As a quick reminder of the previous two chapters, we introduced a banking environment in **chapter 3** and narrated on the specificities of our model environment. Our banking system consists of two banks, bank A and B, and the banks have common investments in a risky technology and are perceived to be connected to a common macroeconomic fundamental that is not publicly observed but whose probability distribution follows a Bernoulli distribution. Depositors in each bank are assumed to receive a noisy signal of their bank's idiosyncratic fundamentals and these fundamentals affect the returns on the risky investment. The banks are engaged in maturity transformation i.e accept deposits from the public, decide on the optimal investment and offer demand deposit contracts to depositors. Depositors base their decision to stay or withdraw on their private signals. The equilibrium structure of the game is such that depositors in bank A, are assumed to move first. The event in bank A becomes public knowledge and then, depositors in bank B are assumed to take their decision, after observing their private information and the public signal of the event that occurred in the first bank.

In **Chapter 4**, we were interested in building on this banking environment by characterising the equilibrium profile of the dynamic Bayesian game between depositors of banks A and B. We assume that depositors in each bank follow a trigger strategy i.e they decide to stay if their private signal is above a threshold and withdraw if it lies below the threshold. We characterise the Perfect Bayesian Equilibrium (PBE) of the dynamic game by deriving the best-response correspondences for depositors of either bank. Depositors in bank A decide on their action by observing their type i.e their private signals and a prior estimate of the state of the common macroeconomic fundamental. Those in bank B decide on their action by basing their decisions to stay or withdraw on their private signals and the public event in bank A, which causes them to stochastically update their posterior beliefs of the state of the common macroeconomic fundamental. It is this statistical reassessment of the state of the common macroeconomic fundamental, which constitutes the informational spillover channel in our model. An interesting profile of our dynamic Bayesian setup is that we can represent it as coordination games for depositors of bank A and bank B, with each coordination game being linked though the informational channel that is created through Bayesian updating. Due to strategic payoff independence across banks, depositors' private signals coordinate their decision and determine the equilibrium threshold. The Bayesian updating process by those depositors in bank B, affects the location of that threshold. Banks fail for fundamentals that lie below the equilibrium threshold and succeed in the reverse case. Thus, the location of the threshold equilibrium affects the probability of bank failures or successes. An interesting finding of **chapter 4** was that, given our model specificity, the threshold equilibrium can be represented as a PBE. This helps us to simplify the analysis and allows us to focus on threshold equilibria for interpretation of results and anything that follows. In particular, we show that, upon observing a failure of bank A, the equilibrium threshold for depositors of bank B rises i.e bank B fails for a longer range of its idiosyncratic fundamentals.

In his chapter, we focus on the concept of banking panic transmission and on the concepts of 'contagion' and 'correlation'. There is no 'one-size-fits-all' definition of financial contagion given by the literature. The existence of a common macroeconomic fundamental in our model, nonetheless, complicates matters. There may be multiple bank failures due to an adverse macroeconomic fundamental to which both banks are commonly exposed to. But that does not necessarily mean that one bank failure is actually causing the other. For instance, if the two banks have assets denominated in one currency and liabilities denominated in another currency, a currency change will affect both banks together in a similar way. This common failure is merely due to a common exposure which exists in all states of the world, to the exchange rate and is not what we are primarily concerned with here. **Chapter 5** endeavours to draw the line between instances in which a transmission of banking failure is exclusively due to perceived deterioration of the state of the common fundamental (correlatedness) and instances in which this transmission of failures across banks is due to changes in behaviour of depositors in bank B exclusively due to the observed event in bank A (contagion). We investigate whether, for banks with common exposure, these concepts are mutually exclusive or whether they are indissociable from each other and arise from the same source.

An important difference that we make in developing the concept of contagion is that, unlike in the existing literature (Allen and Gale (2000), Dasgupta (2004), Rochet and Tirole (1996), Chen (1999), Vaugirard (2005)) which focuses on contagion as 'interdependence', we develop a theoretical model of a robust and more plausible concept of contagion - that of 'excess correlation'. In an empirical paper on the bonds market, Forbes and Rigobon (2002) assert that interdependence may be regarded as a weak aspect of contagion. A more plausible concept of contagion is one that focuses on excess correlation. In a similar line of thought, Pesaran and Pick (2007) show, using interest rates in European bonds market, that interdependence may not lead to econometrically robust models of contagion. They argue that 'excess correlation' provides a more robust account of contagion from an econometric perspective. The paradigm we develop, is meant to be a theoretical adaptation of the empirical results of Pesaran and Pick (2007). Our approach endogenises the concept of banking contagion by representing it by discontinuities in the transmission mechanism of a crisis across banks. It is similar to the idea of an endogenous state-contingent change in cross-bank correlation. There is a positive range of the idiosyncratic fundamental in which the second bank fails (succeeds) if and only if the first bank has failed (succeeded). Thus, the issue of causation that undepins contagion in our setup, can be represented as one of excess correlation between banks in some states of the world compared to others. Developing a theoretical model of contagion based on a concept that has been proved to yield empirically plausible and robust results, has its merits. We are able to throw light on the interplay between private and public signals in generating results and to contribute to the debate on policy implementation in ways that cannot be captured by single-bank models (or even by existing multi-bank models that explain contagion from the narrower concept of interdependence).

A second notable contribution of **chapter 5** to the literature is that we are capable of characterising the occurrence of events across banks as a function of the informational attributes of depositors. The interplay between relative importance of private and public information for depositors of bank B, matters for determining the exact nature of the banking panic transmission. In particular, we can show that, for contagion to occur in equilibrium, depositors of bank B must face *public informational dominance* i.e they attach greater importance to the public event in bank A rather than to their own private information. Instances in which bank B successfully resists a contagious flow from bank A, are those in which there is *private informational dominance*. Here, the private information of bank B depositors is given more attention than the public event they observe about bank A. Here, bank B's performance thus depends relatively more on its idiosyncratic fundamentals and bank B successfully manages to ward off the biasedness that is created by the impact of the public news about bank

A. Allowing for the interplay between private and public signals as a way of triggering events that are conceptually (and empirically robust) is an important contribution that we make.

Our approach is different to Hellwig (2002) who focuses on a static stylized coordination game of incomplete information and who shows how the relative importance of private and public information, may affect the nature of equilibrium (uniqueness as opposed to multiple equilibria). In our work, we are interested in showing how this interplay affects the events across banks rather than the nature of equilibrium. Our interpretation of contagion as one represented by public informational dominance, is similar to the herding model result of Banerjee (1992). However, unlike in heding models, there is no stop in information aggregation in our setup. Depositors do not ignore their private signals at any point. They simply place relative importance on one type of signal relative to another. For instance, if contagion occurs, those of bank B attach relatively more importance to the public news than to their own private information. Also, unlike herding models in which there is only one outcome after information aggregation stops (i.e herding outcome), our model is consistent with different permuations of outcomes, depending on the relative importance of private vs public information in depositors' information set. For instance, if private informational dominance occurs, bank B will still be able to avoid the contagious impact that a failure of bank A entails.

Our theoretical modelling structure provides a robust account of contagion which, while meticulous and articulate in its conceptual definition, yields results and predictions that corroborate with empirical evidence and that are capable of explaining key stylized facts. Prior to the East Asian financial turmoil of 1997, there was little analysis of why country-specific crises could spread internationally. The Asian crisis of 1997 appeared with its conundrum: Why was South Korea, a member of OECD and boasting strong economic fundamentals, 'infected' by what was happening elsewhere in the region ? Why was Hong Kong relatively less affected than Malaysia ? How could the Asian turmoil have possibly spilled over to Russia ? How could the Russian sovereign debt default affect Brazil, despite the lack of trade and financial flows between the two countries ? Existing papers in the literature fail to provide a simultaneous explanation to all three puzzles because they focus on interdependence. We provide the answers to these puzzles in **chapter 5**.

Compared to one-bank models, our approach provides fresh and innovative contributions to the art of policy administration orchestrated by Central Banks. By being capable of distinguishing between contagion and correlation as equilibrium phenomena, our model can provide useful guidance for the design of microprudential and macroprudential regulations. While Macroprudential regulation is needed in case of correlation, microprudential policy is warranted in case of contagion. In addition, we pioneer the concept of *'intertemporal banking substitution'*, as possible conjecture that may occur in a multi-bank setting, when microprudential policy measures like Suspension-of-Convertibility (SOC), are administered at a crisis catalyst bank.

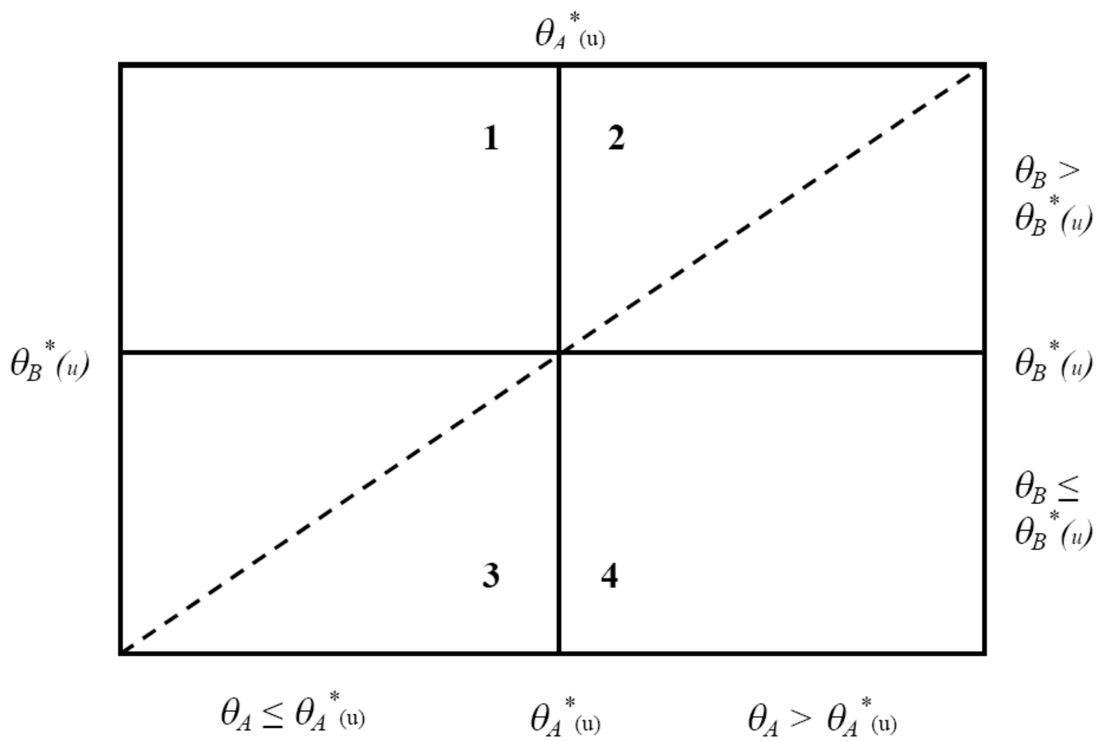
As potential insurance against such intertemporal substitution, we rationalise the case for the adoption of confidence safeguards throughout the economy, as economy-wide insurance mechanism designed to contain the effects of informational spillovers that result from enactment of prudential measures at a crisis-catalyst bank. This constitutes a significant improvement over existing multi-bank models in the literature. These models describe contagion as interdependence and offer practically the same guidance to the nature of policy-making, as single-bank models. The idea is that the conduit that spreads a crisis across banks is the same channel that pre-empts the transmission if appropriate policies are administered at the crisis-catalyst bank. For instance, in Allen and Gale (2000), SOC at a crisis-catalyst bank will always prevent contagion since, by definition, it helps to preserve the balance sheet of the crisis catalyst bank. Our paradigm is different in that, with public information, a policy being administered at one bank, may create a crisis channel of its own if the policy is interpreted negatively by depositors in the rest of the banking system. We provide some examples to illustrate the validity of this important point. Although written with the East Asian turmoil in mind, we endeavour, where possible, to relate the contributions of our research work to the contemporary financial crisis of 2007-2008. The Northern Rock crisis in the UK in 2007 is used as example in **chapter 5** to illustrate how our framework (embodied in **chapters 3, 4** and **5**) can be used to rationalise the occurrence of certain events that had occurred in the current financial turmoil.

The rest of the chapter is organised as follows: **Section 5.1** and **5.2** deal with the nature of equilibrium financial contagion and correlation and attempts to determine their relative importance in a banking panic transmission event. The section also relates contagion and correlation to the informational attributes of depositors of bank B. The concepts of public informational dominance and private informational dominance are introduced in **section 5.3** and are formally linked to the nature of events that occur. The section ends with some general properties of contagion and correlation in equilibrium. An interesting fact here is that, with uniform prior and posterior distributions of the common macroeconomic fundamental, the incidence of contagion and correlation in our setup is zero. This differs significantly from Dasgupta (2004) whose model relates the incidence of contagion to the size of interbank deposit contracts. **Section 5.4** discusses the policy implications of our paradigm. Finally, **section 5.5** concludes.

5.2 Financial Contagion as State-Contingent Change in Cross-Bank Correlation

To be able to define financial contagion appropriately within the setup we have adopted, it is important to stress on the cause-effect relationship that underpins the concept. Heuristically, we could view financial contagion as '*an event that occurs when the failure of bank A causes bank B to fail, when bank B would not have failed otherwise*'. Note the importance of the second part of the statement

FIGURE 5.1: 'Autarky' case / 'Tranquil' State - Assume that the State of Common Macroeconomic Fundamental is u



'*....when bank B would not have failed otherwise......'*. This implies that, in our definition, without bank A, bank B could fail for other reasons (e.g its idiosyncratic fundamental is too low) or it could possibly not fail at all. What the statement is really saying, is that the performance of bank A, by itself, will *increase* the likelihood of failure of bank B over what could possibly have happened without the presence of bank A. Before moving on further, we must first elicit the conditions under which this will hold true. Then we shall formalise the concept of contagion through appropriate use of diagrams. Consider Figure 5.1.

Figure 5.1 highlights the unique threshold in each bank. For the moment, let us forget about the dynamics that will cause $\theta_A^*(u)$ and $\theta_B^*(u)$ to vary and attempt to situate what we have learned in the previous topic in the above diagram. Thus, initially, we set $\theta_A^*(u) = \theta_B^*(u)$ and, with slight abuse of language, shall refer to this as the *autarky situation*[1] or as in the introduction, the 'tranquil' state. Quadrants 3 and 2 show similar results in both banks. Quadrant 3 depicts the phenomenon of both banks failing (i.e $\theta_A \leq \theta_A^*(u)$, $\theta_B \leq \theta_B^*(u)$) while quadrant 2 shows both banks succeeding or 'not failing' (i.e $\theta_A > \theta_A^*(u)$, $\theta_B > \theta_B^*(u)$). Quadrants 1 and 4 show mixed result. The former depicts the success of bank B but failure of bank A (i.e $\theta_A \leq \theta_A^*(u)$, $\theta_B > \theta_B^*(u)$) while the latter shows the reverse effects (i.e $\theta_A > \theta_A^*(u)$, $\theta_B \leq \theta_B^*(u)$).

How would our concept of financial contagion fit into the diagram? Could we possibly argue that contagion is an event that occurs in quadrant 3? Doing so would merely show the joint occurrence of failures of bank A and B but there is nothing to tell us about the causation of the crises. Any permutation of events is possible in that quadrant. Bank B can fail for reasons other than failure of bank A and vice versa. To get a proper representation of financial contagion, we abstract from what may commonly be driving the performance of both banks. This is done by controlling for the level of the common macroeconomic fundamental. The aim is to assess mathematically how the failure of bank A, by itself, can cause the failure of bank B after controlling for the common fundamental.

Thus, we must show that, whenever bank A fails (i.e $\theta_A \leq \theta_A^*(u)$), the probability of bank B failing for a *given* level of macroeconomic fundamental, will be higher than $\theta_B^*(u)$. For each of the possible two realisations of the common macroeconomic fundamental, this probability can be assessed. What extra feature does the failure of bank A has on bank B's threshold ? It was shown in proposition 4.5 (of the previous chapter) that, upon failure of bank A, the trigger of bank B is adjusted in such a way that depositors in bank B are

[1] Autarky typically refers to absence of trade but here, it means that there is no interraction among the banks. Depositors of each bank behave as if the other bank did not exist. Due to identical endowments and similar returns structure, it is obvious that $\theta_A^*(u) = \theta_B^*(u)$.

more likely to share a similar fate to those of bank A. We denoted that trigger $\theta_B^{F_A}(u)$. Assuming that the common macroeconomic fundamental is in its bad state, the cause-effect relationship between failure of bank A and failure of bank B can be represented as events Pr $(\theta_B \leq \theta_B^* \ (u) \mid \theta_A \leq \theta_A^* \ (u) \cap \{u = u_{Bad}\})$.

Recall that $\Pr(\theta_B \leq \theta_B^*(u) \mid \theta_A \leq \theta_A^* \ (u) \cap \{u = u_{Bad}\}) \equiv \theta_{B,u_{Bad}}^{F_A}$. We referred to this as the threshold for bank B but computed with conditional probability, $\Pr(u = u_{Bad} \mid F_A)$ which we gave earlier as $\frac{k \ \theta_A^*(u_{Bad})}{k \ \theta_A^*(u_{Bad}) \ + \ (1-k)\theta_A^*(u_{Bad})}$. Clearly, $\theta_{B,u_{Bad}}^{F_A} > \theta_B^* \ (u)$, where $\theta_B^* \ (u)$ is computed as the threshold of bank B in the autarky case.

Similarly, we computed the event that bank B fails conditional on success of bank A and the state of the common fundamental being bad as $\Pr(\theta_B \leq \theta_B^*(u) \mid \theta_A > \theta_A^* \ (u) \cap \{u = u_{Bad}\}) \equiv \theta_{B,u_{Bad}}^{S_A}$. This refers to the threshold of bank B computed with conditional probability $\Pr(u = u_{Bad} \mid S_A)$ which we gave earlier as $\frac{k \ (1-\theta_A^*(u_{Bad}))}{k \ (1-\theta_A^*(u_{Bad})) \ + \ (1-k)(1-\theta_A^*(u_G))}$. Clearly, $\theta_{B,u_{Bad}}^{S_A} \leq \theta_B^* \ (u)$, where $\theta_B^* \ (u)$ is computed for bank B as in the autarky case. We present the autarky thresholds $\theta_A^* \ (u)$, $\theta_B^* \ (u)$, $\theta_{B,u_{Bad}}^{S_A}$ and $\theta_{B,u_{Bad}}^{F_A}$ in Figure 5.2(a) (please turn next page for illustration).

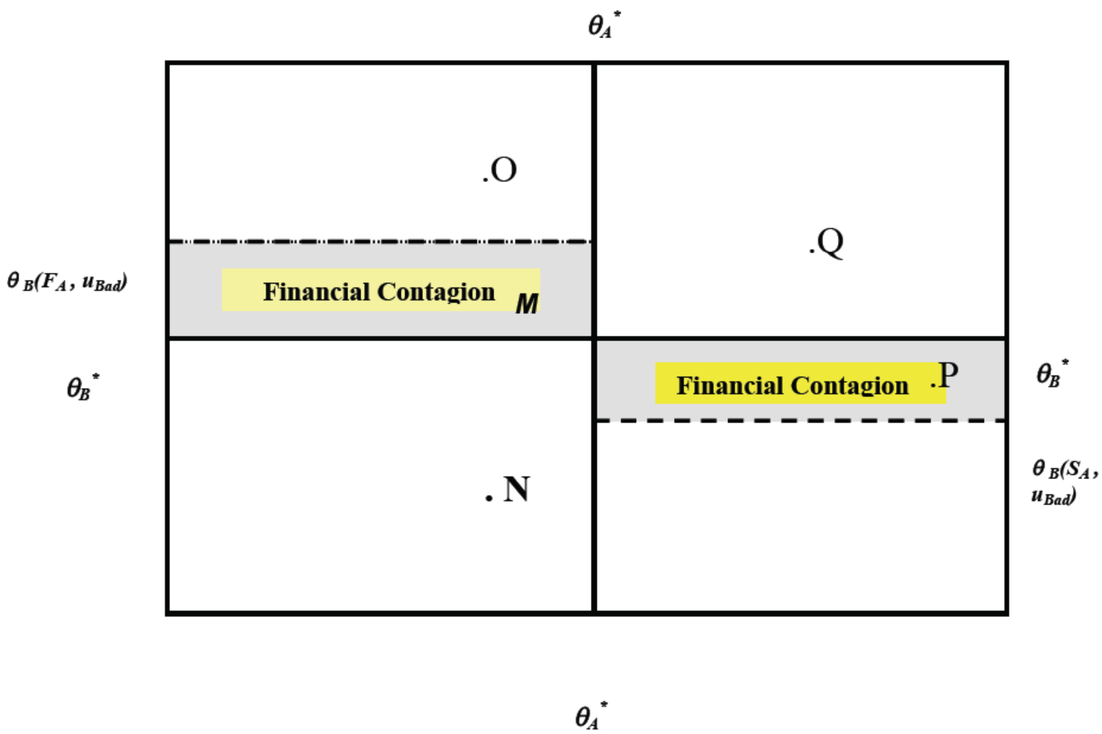
The representation in Figure 5.2(a) enable us formalise the definition of financial contagion as follows:

Definition 5.1: *(Formal) (**Financial Contagion**) For the part of the game between $\Gamma_{A,t=1}$ and $\Gamma_{B,t=1}$ characterised by the existence of a unique threshold in the depositors' game, financial contagion is said to occur when:*

For $\theta_A \in \left[u^G \ , \ u^{Bad} + z\right]$, $\theta_B \in \left[u^G \ , \ u^{Bad} + z\right]$ and conditional on state u

Either (1) *event*
$\left\{\{ \ \theta_A \leq \theta_A^* \ (u)\} \quad \cap \ \{ \ \theta_B^*(u) \leq \ \theta_B \leq \theta_{B,u}^{F_A}\}\right\}$ *for a given macroeconomic state* u

FIGURE 5.2 (a): Depiction of Financial Contagion



The probability of contagion is a weighted average of the above event, with each weight corresponding to the probability distribution underlying the particular state of the macroeconomic fundamental:

Pr(Contagious Failures)
$= k\left(\theta^{F_A}_{B,u_{Bad}} - \theta^*_B(u^{Bad})\right)\left(\theta^*_A\left(u^{Bad}\right) - u^{Bad}\right) +$
$(1-k)\left(\theta^{F_A}_{B,u_G} - \theta^*_B(u^G)\right)\left(\theta^*_A\left(u^G\right) - u^G\right)$

Or **(2)** *event*
$\left\{\{\ \theta_A > \theta^*_A(u)\ \} \cap \quad \{\theta^{S_A}_{B,u} \leq \theta_B \leq \theta^*_B(u)\}\right\}$*for a given macroeconomic state* u

The probability of contagion is a weighted average of the above event, with each weight corresponding to the probability distribution underlying the particular state of the macroeconomic fundamental:

P(Contagious Success)
$= k\left(\theta^*_B(u^{Bad}) - \theta^{S_A}_{B,u^{Bad}}\right)\left(\left(u^{Bad} + z\right) - \theta^*_A(u^{Bad})\right) +$
$(1-k)\left(\theta^*_B(u^G) - \theta^{S_A}_{B,u^G}\right)\left(\left(u^G + z\right) - \theta^*_A(u^G)\right)$

Notice that in Figure 5.2(a), each form of contagion is represented by the two shaded segments of the graphs. It is only in these two segments that we can reasonably have a cause-effect relationship. For instance, assume that the state of the common macroeconomic fundamental is bad. We have argued that when bank A fails, the trigger of bank B is revised upwards taking into account the fact that bad news have raised the trigger from $\theta^*_B(u^{Bad}\ )$ to $\theta^{F_A}_{B,u_{Bad}}$. This extra increase in the trigger due to the event in bank A is what the shaded segment on the left of Figure 5.2(a) is all about. Here, bad news about bank A has altered the behaviour of depositors in bank B such that, given the level of the common macroeconomic fundamental, bank B fails for a wider range of its own fundamentals. The difference $\theta^{F_A}_{B,u_{Bad}} - \theta^*_B(u^{Bad})$ represents this cause-effect relationship.

Point M in Figure 5.2(a) shows a case where failure of bank A can cause bank B to fail. Without interactions between the two banks, point M would have represented an outcome such that depositors of bank A would have chosen to remain invested, given the strategies they pursue. The possibility of interactions between banks means that the failure of bank A leads to an updated assessment of the prior states of the common fundamental by depositors of bank B such that the threshold of bank B is raised relative to the autarkic level. Point M thus represents a case of θ_B being less than the new threshold $\theta^{F_A}_{B,u_{Bad}}$. Thus depositors in bank B withdraw when they would not have done so otherwise. Like point M, any point within the left shaded area of Figure 5.2(a), represents a case of success of bank B in autarky case but failure with interaction case. Notice that points below the horizontal (dotted) line $\theta^*_B\left(u^{Bad}\right)$ represent failure of bank B, even though bank A does not exist. Point N, thus cannot represent financial contagion because even though both banks A and B fail, bank B would have failed anyway even without bank A's presence.

By the same token, success of bank A will lower the trigger of bank B from $\theta^*_B\left(u^{Bad}\right)$ to $\theta^{S_A}_{B,u_{Bad}}$ assuming that the common macroeconomic fundamental is in its bad state. That extra fall in the trigger of bank B due to the event of bank A also depicts financial contagion (shown as the right hand shaded segment of Figure 5.2(a)). Ostensibly, the arguments also run through if the common fundamental was in the good state (i.e $u = u_G$). Without interaction, point P would have represented a case of bank B failure in the autarkic case. Allowing for interaction between banks leads to an updated assessment of the prior states of the common fundamental such that the new trigger becomes $\theta^{S_A}_{B,u_G}$. Point P represents a case of bank failure without interaction but a case of no bank failure with interaction. Like point P, any point in the shaded area on the right of Figure 5.2(a) represents a case of success of bank B exclusively due to success of bank A.

Definition 5.2: *(Informal) (**Financial Contagion**) Significant change in the co-movements of events across banks, conditional on an event occurring in the first bank.*

This concept of contagion is highly appealing and largely fits what is commonly perceived as a by-product of natural correlation: that the intensity of the transmission mechanism channel is different after a shock plaguing one bank. In all states of the world, the two banks are correlated but in the non-tranquil state, there is an extra element to this transmission mechanism that appears in the form of excessive correlatedness. This refers to investors of the second bank changing their behaviour just because of the event in the first bank and is what constitutes contagion in our paper. By stressing on the quantitative element (i.e 'significant change'), it conveys the notion of contagion as representing excessive co-movements, relative to some normal benchmark. The purpose of this section was to define this 'normal' yardstick and to contrast the 'excess' with respect to it.

Definition 5.3: *(Formal) (**Financial Correlation**) For the game between $\Gamma_{A,t=1}$ and $\Gamma_{B,t=1}$ characterised by the existence of a threshold equilibrium in the depositors' game, financial correlation is said to occur when:*

For $\theta_A \in \left[u^G \ , \ u^{Bad} + z\right] \ , \ \ \theta_B \in \left[u^G \ , \ u^{Bad} + z\right]$ and conditional on state u

Either(1) *"Negative Correlatedness"*

$\{\{u \leq \ \theta_A \leq \theta^*_A\,(u)\} \ \ \cap \ \{ \ u \leq \ \theta_B \leq \theta^*_B(u)\}\}$ *for a given macroeconomic state* u

The probability of negative correlatedness is a weighted average of the above event, with each weight corresponding to the probability of a particular state of the macroeconomic fundamental occurring:

$P(\text{Correlated Failures})$

$= k\left(\theta^*_B(u^{Bad}) - u^{Bad}\ \right)\left(\theta^*_A\left(u^{Bad}\right) - \ u^{Bad}\right) +$

$(1-k)\left(\theta^*_B(u^G) - \ u^G\right)\left(\theta^*_A(u^G) - \ u^G\right)$

Or (2) *"Positive Correlatedness"*

$\{\{ \ (u+z) > \theta_A > \theta^*_A\,(u) \ \} \cap \ \ \{\theta^*_B(u) \leq \theta_B \leq (u+z)\} \ \}$*for a given macroeconomic state* u

The probability of postive correlatedness is a weighted average of the above event, with each weight corresponding to the probability of a particular state of the macroeconomic fundamental occurring:

$P(\text{Positive Correlatedness})$
$= k\left(\left(u^{Bad}+z\right)-\ \theta_B^*(u^{Bad})\right)\left(\left(u^{Bad}+z\right)-\theta_A^*\left(u^{Bad}\right)\right)+$
$(1-k)\left(\left(u^{G}+z\right)-\ \theta_B^*(u^{G})\right)\left(\left(u^{G}+z\right)-\theta_A^*\left(u^{G}\right)\right)$

The presence of common exposure to the macroeconomic fundamental means that the performance of bank A and bank B will inexorably be driven by common factors and will follow the same cycle in all states of the world .

Our ability to explain contagion endogenously as a case of 'excessive correlation' departs fundamentally from the existing literature (Rochet and Tirole (1996), Chen (1999), Allen and Gale (2000), Dasgupta (2004)), which models contagion essentially as 'interdependence'. Research on contagion in the bonds market and on the stock market by Forbes and Rigobon (2002), showed that interdependence could be interpreted as the weakest aspect of contagion. The main reason for such an interpretation of contagion being regarded as 'weak' is that the conduit that connects entities remains the same in all states of the world. Thus, in crisis-scenarios, the main channel that contagiously transmits a crisis from one entity to another, is essentially the same channel that achieves the benefit of forming that connection between the two entities in a non-crisis scenario. In Allen and Gale (2000), for instance, banks benefit from cross-insuring their deposits when regional liquidity shocks are negatively correlated. In a crisis situation, this channel transmist a crisis from bank to bank if the network structure that links banks, is incomplete. Similarly, in Dasgupta (2004), banks engage in cross-holding interbank deposit contracts. The optimal interbank contract trades off the benefit of regional liquidity insurance (which is provided by the interbank connection between balance sheet of banks) and the endogenous probabilit of a contagious failure across banks. In both, Allen and Gale (2000) and Dasgupta (2004), 'interdependence' is provided by the interbank channel that directly connects banks. This channel remains in all states of the world.

More recently, Pesaran and Pick (2007) developed an empirical model of contagion, to explain why contagion viewed as 'interdependence' does not yield empirically robust results. They argue that, using evidence from interest rates in Europe, that models that explain contagion as 'excess correlation' are most robust. With excess correlation, there is an extra channel that exists in crisis scenarios, relative to non-crisis scenarios. The issue of causation is important as well. This extra channel is responsible for *causing* a second entity to fail (if and only if a first entity has failed), when no such second entity failure would have occured otherwise. Our results corroborate the findings of Pesaran and Pick (2007). We show that when contagion occurs, the issue of causation is at heart of the transmission mechanism. In the shaded areas in Figure 5.2(a) for instance, bank B fails (succeeds) just because bank A ahs failed (succeeded). Furthermore, the transmission conduit that leads to contagion across banks, exists in particular states of the world only. For instance, in the state of the world in which bank A fails, there is negative informational spillover on depositors of bank B. The latter will weigh this public signal with their private signal before deciding whether to withdraw. If they do, then a channel has been created by the public signal encapsulated by informational spillovers. The same process works in an opposite fashion in a state of the world in which bank A succeeds. Most importantly, whether positive or negative contagion occurs, we can endogenously show contagion as a case in which the correlation between banks becomes excessive. Our approach of contagion thus satisfies the robustness definition of contagion provided by Forbes and Rigobon (2002), and can be represented as a theoretical representation of Pesaran and Pick (2007)'s empirical results.

With contagion being depicted as a case of an excess in natural correlation, we next turn to rationalising the case for contagion as a function of informational attributes of depositors.

5.3 Public Informational Dominance vs Private Informational Dominance

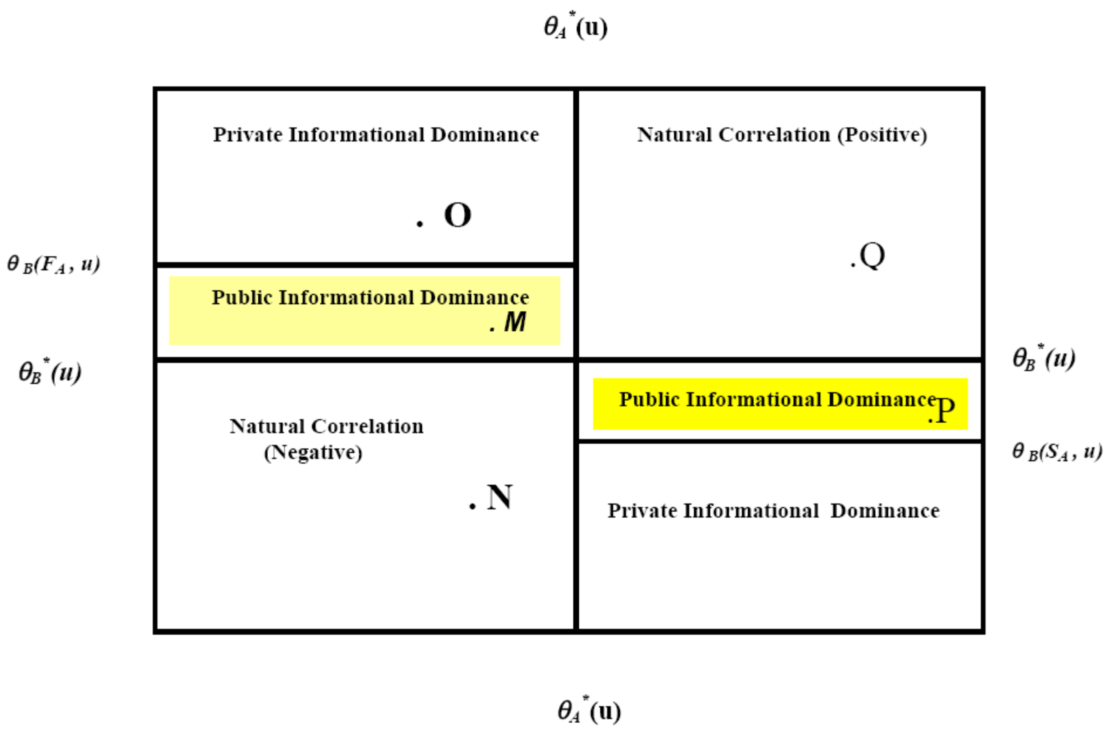
What constitutes the driving force behind the crucial difference between contagion and correlation ? Intuitively, the difference in the results obtained can be attributed to the relative importance of information in depositors' strategy. We know that, by construction, the banks have a correlated performance in all states of the world. Thus, a boom in the performance of portfolios in the hedge fund will drive their performance sky-high and a recession will result in a lacklustre performance. The shaded rectangles in Figure 5.2(a) in the graphical appendix represent cases of "excess correlation" . The location of a given point reflects the location of the idiosyncratic fundamental of each bank. With precise private signals, the location of point M also signifies the relative importance of private signals in depositors' strategy. Consider point M for instance. From the perspective of bank A, M suggests that $\theta_A \leq \theta_A^* (u)$. Given their strategy, depositors of bank A will withdraw and, by proposition 4.3 (of the previous chapter), bank A fails since the set of signals that depositors receive will cluster around θ_A . From the perspective of bank B, point M suggests that a success of bank B in the autarky case but a failure in the case in which depositors are allowed to observe the event in bank A. The location of θ_B at point M relative to the autarky case, reflects the location of private signals of depositors of bank B. Thus, the (vertical) distance of between the θ_B at point M and the autarkic threshold $\theta_B^* (u)$ denotes *the importance of private signals* in depositors' strategy. Observing the failure of bank A leads all depositors of bank B to update their beliefs about the state of the common macroeconomic fundamental, such that the threshold of bank B increases from $\theta_B^* (u)$ to $\theta_B^{F_A} (u)$. The distance $\theta_B^{F_A} (u) - \theta_B^* (u)$ represents the increased probability of failure of bank B exclusively due to the observed public event in bank A. Thus, the distance $\theta_B^{F_A} (u) - \theta_B^* (u)$ represents the *importance of public signals* in depositors' strategy.

The classification of an event as correlation, contagion or neither of these depends on the relative importance of private and public signals in bank B depositors' decision set. Point M, for instance, is a point at which the relative importance of the private information is less than the relative importance of the public infomation. We thus have *public informational dominance* here. Any point in the shaded area is characterised by public informational dominance. When this happens, an event in bank A will always contagiously spread to bank B with the definition of contagion we adopted earlier. Point P, associated with a success of bank A, is also characterised by public informational dominance by virtue of the same features characterising the informational attributes in depositors' decisions (as in point M). Please refer to Figure 5.3 (next page) for an illustration.

Point O in Figure 5.3, characterised by failure of bank A, is one in which the vertical location of θ_B relative to the autarkic threshold $\theta_B^* (u)$, exceeds the vertical distance $\theta_B^{F_A} (u) - \theta_B^* (u)$. When this takes place, the private signals of depositors of bank B are given relatively more importance than the public signal emanating from the observed event in bank A. This is dubbed *private informational dominance.* Any point in the quadrant that is north of the shaded area containing point M, is characterised by private informational dominance. Here, intuitively, the depositors of bank B attach more importance to their private signals (which are high because they are clustered around a high θ_B) than to the publicly observed event. Thus, a strong idiosyncratic performance of bank B may ward off any informational attributes coming from a publicly observed event such that no contagion occurs. In a similar line of thought, any point in the quadrant south of the shaded area containing point P will be characterised by strict private informational dominance. The intuition is that, while bank A has succeeded (the relative importance of public information for depositors of bank B being represented by vertical distance $\theta_B^* (u) - \theta_B^{S_A} (u)$), the relative importance of private information (measured by vertical distance $\theta_B^* (u) - \theta_B$) is given more importance in the decision set of depositors of bank

FIGURE 5.3 : Informational Attributes – Assume Macroeconomic Fundamental State is u

Contagion vs Correlation: Public Informational Dominance vs Private Informational Dominance



B. The performance of bank B is thus driven relatively more by the private information of its depositors in this quadrant. Thus, bank B fails.

Points in any other quadrants (e.g point N in the south-west quadrant $(\theta_A \leq \theta_A^* (u), \; \theta_B \leq \theta_B^* (u))$ or point Q in the north-east quadrant $(\theta_A > \theta_A^* (u), \; \theta_B > \theta_B^* (u))$ represent cases of natural correlation. Here, the performances of banks are driven by their idiosyncratic fundamentals with or without interraction. Banks register identical results in all states of the world. There is no difference between autarky and interraction cases. Bayesian updating about the state of the common macroeconomic fundamental has no bite on the results. To sum up:

General Corollary (Public Informational Dominance vs Private Informational Dominance) *The performance space of the two banks can be segregated into three main events for bank B: Correlation, Contagion and None.*

(**Correlation**) *Banks are naturally correlated in all states of the world due to identical investment in a hedge fund affected by some common macroeconomic fundamental.*

(**Contagion**) *Contagion, derived as an excess in this natural correlation, occurs due to public informational dominance in depositors' decision set. Here, depositors of bank B give relatively more importance to the public news emanating from the event in bank A than to their private information, such that bank B's performance follows the public news and suffers a fate identical to that of bank A.*

(**None**) *The case in which bank B does not share the same fate as bank A is a case in which there is private informational dominance. Here, the private information of depositors is so strong (upwards or downwards) that it wards off completely the public event of bank A's performance. Bank B's performance is driven more by its idiosyncratic fundamentals.*

In a static game of incomplete information, Hellwig (2002) derives the necessary and sufficient conditions for there to be uniqueness as opposed to multiplicity of equilibria. The occurence of the specific type of equilibrium depends on the specific realisations of the private signal and of the public signal. The discussion of the results we obtain above about th einterplay between private and public information, can be thought as an adaptation of Hellwig (2002) to the banking world. However, our approach differs from Hellwig in three main ways. We deal with dynamic Bayesian games (i.e sequential move games with incomplete information) that are applied to a banking context. In Hellwig (2002), the game is stylized and static. Furthermore, our private signals and public signal are on different variables. The private signals of depositors in each bank concern the idiosyncratic fundamental of that bank only and the public signal is related to an endogenously observed event in bank A. In Hellwig (2002), the private and public signals are on the same variable. Lastly, we are interested in the interplay between private and public informational attributes in triggering events across banks. Hellwig (2002) deals with these attributes as a mechanism for selecting the nature of equilibrium. We studied the nature of equilibrium of our game in **chapter 4**.

Our fundamental result of contagion occurring when there is *public informational dominance*, is similar to the herding result obtained by Banerjee (1992). In herding models, the informational attributes of the game evolve as an implicit learning mechanism. Herding occurs as an equilibrium when information aggregation stops and agents in the continuation game, ignore their private signals and rely on public information alone. Our paradigm differs from the herding models in an important way. Unlike herding models, there is no stop in infomation aggregation. The issue of causation that underpins contagion in our setup, simply occurs when depositors of bank B attach relatively more importance to the public information of the event in bank A, than to their private information. While both informational endowments are still being used, the effect of the public news overshadows that of the private signal, with the result that bank B suffers a similar fate as bank A. Furthermore, we provide microtheoretic account for cases in which this kind of result may be prevented. For instance, bank B may still avoid a failure (despite bank A failing) if its depositors have extra strong private signals that overpower the public news of bank A's failure. Thus, unlike herding models, in which only one result occurs after information aggregation stops, in our model, different permutations in results are still possible, depending on the relative importance of private vs public news in depositors' information set.

5.3.1 Properties of Contagion and of Correlation as Equilibrium Phenomena

Property 5.1: *Conditional on the state of the common macroeconomic fundamental being bad, the probability of having bad contagion (correlation) exceeds that of having good contagion (correlation)*

Illustration:

P(Contagious Failures) > P(Contagious Success)

$$\left(\theta^{F_A}_{B,u_{Bad}} - \theta^*_B(u^{Bad})\right)\left(\theta^*_A\left(u^{Bad}\right) - u^{Bad}\right) >$$
$$\left(\theta^*_B(u^{Bad}) - \theta^{S_A}_{B,u^{Bad}}\right)\left(\left(u^{Bad} + z\right) - \theta^*_A(u^{Bad})\right)$$

P(Correlated Failures) > P(Correlated Success)

$$\left(\theta^*_B(u^{Bad}) - u^{Bad}\right)\left(\theta^*_A\left(u^{Bad}\right) - u^{Bad}\right) >$$
$$\left(\left(u^{Bad} + z\right) - \theta^*_B(u^{Bad})\right)\left(\left(u^{Bad} + z\right) - \theta^*_A\left(u^{Bad}\right)\right)$$

Property 5.2: *Conditional on the state of the common macroeconomic fundamental being good, the probability of good contagion (correlation) exceeds that of bad contagion (correlation)*

Illustration:

P(Contagious Success) > P(Contagious Failure)

$$\left(\theta^*_B(u^G) - \theta^{S_A}_{B,u^G}\right)\left(\left(u^G + z\right) - \theta^*_A\left(u^G\right)\right) > \left(\theta^{F_A}_{B,u^G} - \theta^*_B(u^G)\right)\left(\theta^*_A\left(u^G\right) - \left(u^G\right)\right)$$

P(Correlated Success) > P(Correlated Failure)

$$\left(\left(u^G + z\right) - \theta^*_B(u^G)\right)\left(\left(u^G + z\right) - \theta^*_A(u^G)\right) > \left(\theta^*_B(u^G) - u^G\right)\left(\theta^*_A\left(u^G\right) - u^G\right)$$

The relative importance of contagion v/s correlation depends on the particular values that threshold parameters take.

While properties 5.1 and 5.2 establish that we can unambiguously rank the contagious failures and successes of a bank as well as the correlated failures and successes, there is no light on the issue of comparing contagious performance and a correlated performance. Judging whether a multiple bank shock is more a matter of correlation than of contagion, is entirely dependent on parametric values that thresholds may have. To take an example, Figures 5.2(a) and 5.3 have been drawn such that correlation is relatively more important than contagion. We could well have illustrated an interpretation of banking performance using the illustrations from Figures 5.2(b)-(d) in the section that immediately follows the conclusion of this chapter. In this case, Figure 5.2(c) shows that, conditional on the macroeconomic fundamental being in its bad state, for instance, contagious bank failures have a higher probability than correlated bank failures (where the relative importance depends on the relative area sizes, depicting their respective probabilities). Similar interpretations can be derived from arbitrary constellation of figures. Figure 5.2(d) in the same section, shows that, conditional on macroeconomic fundamental being good, positive contagious probability may exceed positive correlatedness. Gauging the size of a contagious event relative to a correlated event is of primacy importance to policymakers since, compared to correlation, contagion has different implications for policymaking. We return to the implications for policymaking in the next section of this chapter

Property 5.3: (**Incidence of Contagion is zero due to uniform distribution of fundamental and error technology**)

Interpret 'Incidence' here as referring to Net Contagion weighted appropriately by the prior probability distribution over the states of the common macroeconomic fundamental. The incidence of contagion is zero.

Proof. T*he incidence is given by:*

$$\begin{aligned}
&k\left(\theta^{F_A}_{B,u_{Bad}} - \theta^*_B(u^{Bad})\right)\left(\theta^*_A\left(u^{Bad}\right) - u^{Bad}\right)\\
&-k\left(\theta^*_B(u^{Bad}) - \theta^{S_A}_{B,u^{Bad}}\right)\left(\left(u^{Bad}+z\right) - \theta^*_A\left(u^{Bad}\right)\right)\\
&+(1-k)\left(\theta^{F_A}_{B,u^G} - \theta^*_B(u^G)\right)\left(\theta^*_A\left(u^G\right) - u^G\right)\\
&-(1-k)\left(\theta^*_B(u^G) - \theta^{S_A}_{B,u^G}\right)\left(\left(u^G+z\right) - \theta^*_A\right) = 0 \qquad \blacksquare
\end{aligned}$$

Property 5.4: (**Incidence of Correlation is zero due to uniform distribution of fundamental and error technology**)

Interpret 'Incidence' here as referring to Net Correlation weighted appropriately by the prior probability distribution over the states of the common macroeconomic fundamental. The incidence of correlation is zero.

Proof. *The incidence is given by:*

$$\begin{aligned} & k\left(\theta_B^*(u^{Bad}) - u^{Bad}\right)\left(\theta_A^*\left(u^{Bad}\right) - u^{Bad}\right) \\ & -k\left(\left(u^{Bad}+z\right) - \theta_B^*(u^{Bad})\right)\left(\left(u^{Bad}+z\right) - \theta_A^*\left(u^{Bad}\right)\right) \\ & +(1-k)\left(\theta_B^*(u^G) - u^G\right)\left(\theta_A^*\left(u^G\right) - u^G\right) \\ & -(1-k)\left(\left(u^G+z\right) - \theta_B^*(u^G)\right)\left(\left(u^G+z\right) - \theta_A^*\left(u^G\right)\right) = 0 \quad \blacksquare \end{aligned}$$

The importance of a zero incidence in contagion or correlation has implications for econometric techniques designed to predict the occurrence of contagious flows or correlated flows. A zero incidence simply asserts that over the various states of the common macroeconomic fundamental, contagion or correlation do not vary in a particular way with parameters of the model. Our results differ from Dasgupta (2004) who claims that the incidence of contagion is positively related to the size of the interbank market in deposits or loans with the assumption of uniformly distributed fundamentals and error technology. In Dasgupta (2004), the presence of the interbank market makes it a conspicuous candidate for judging the size of contagious flows. While the interbank market provides regional liquidity insurance, it also provides a channel which spreads a failure from bank to bank. There is no direct payoff dependence in our model - the only channel through which infomation flows is the public information channel which affects depositors' beliefs and decisions. Our interpretation of zero incidence follows from the fact that whilst we controlled for the states of the common macroeconomic fundamental to gauge the specific cause-effect relationship, depositors' beliefs net out over the different states of the common fundamental. We opine that while econometric techniques may be helpful in predicting the occurrence of contagious flows when there are well defined direct links, they must be used with caution in models in which informational spillovers link events across banks.

5.4 Practical Relevance and Applications

Though the model of banking panic transmission highlighted in this chapter is admittedly highly theoretical, it has practical relevance and can offer fresh innovative insights into ways in which Central Banks and international institutions such as the IMF must go about designing the regulatory structure. In the following subsections, we present the application of our paper to explaining important puzzles in the literature and we go on to extol on the innovative framework that may be used to analyse policy implications so as to improve on the existing regulatory setting of banks' activities.

5.4.1 Demystifying Important Puzzles

Surveying the empirical literature on financial contagion helps unearth three puzzles about financial contagion, which are inextricably linked to one another:

(Zero-Link Puzzle) *The failure of one financial intermediary sometimes leads to the failure of another intermediary when there is no apparent physical or direct link between them.*

(Clustering Puzzle) *Financial contagion may not arbitrarily spread from one institution to another but rather seems to affect identical institutions only.*

(Avoidance Puzzle) *Among a set of identical countries / institutions, some can avoid a contagious flow whereas others cannot.*

Models of financial contagion that focus on direct links (Allen and Gale (2000) and Dasgupta (2004)) do not explain the zero-link issue. The essence of these models of contagion is the existence of a direct link itself that lies at the heart of spreading a crisis from one bank to another. In Allen and Gale (2000) and Dasgupta (2004), the existence of a network of overlapping interbank claims provides the key propagator channel, such that a bank failure means that another bank will surely suffer a loss of interbank claims. Hence, it is more likely to suffer from the same fate as the first bank. If there were no financial contracts provided by the interbank market for deposits as a way of insuring against regional liquidity shocks, there would no banking panic transmission. The importance of the zero-link puzzle cannot be underestimated though as evidence does seem to suggest that crises often propagate to institutions or countries that share no similarities with the crisis-catalyst institution or country. In our setup, we have shown that, even with no such direct financial links between banks, *contagion may still occur in equilibrium*. Our model can thus explain why events in small economies like Thailand can affect behaviour of investors in, say, Russia, Argentina or Mexico, notwithstanding the insignificance of direct trade or financial links between them.

The second puzzle has been widely documented by Aharony and Swary (1996) who conducted a study of 33 US banks in the mid 1990s and found that the extent of negative impact of contagion is greater for banks that are similar to the failed bank. Ahluwalia (2000) shows that, for a sample of 19 countries and three episodes of crises, a country's vulnerability to contagious crises depends on the visible similarities between this country and the country actually experiencing the crisis. Allen and Gale (2000) and Dasgupta (2004) do not explain the clustering issue because they focus on homogenous banks throughout and the strength of connection provided by the direct link is same for all banks. In our model, we do make the distinction between identical and non-identical banks in that identical banks are those that share a common exposure to the macroeconomic fundamental. If banks were not linked to the common fundamental (i .e were not identical), depositors of the second bank would not have adjusted their beliefs about the macroeconomic fundamental and no crisis would have spilled over to the other bank. The clustering puzzle of contagion was apparent in the Tequila crisis from Mexico to Argentina and Brazil in 1994-95, the East Asian crisis of 1997-98 and the ripple effect of the Russian default in August 1998 on many emerging markets.

The third puzzle represents the antithesis of the clustering puzzle . Among a set of identical countries or institutions, it may not necessarily be the case that all countries suffer a contagious flow when one is hit by a technological / liquidity shock. Some do manage to avoid a contagious flow of financial crisis. Countries that succeed in pre-empting an overseas financial crisis from affecting them, are those that inevitably have very strong idiosyncratic fundamentals. In our model, a failure of bank A, for instance, may not contagiously spread to bank B if depositors of bank B have strong private signals that dominate any public signal they observe about bank A. For example, in Figure 5.3 above, point O represents such a case. By contrast, point M is one in which the public signal element dominates the private information of depositors (weak idiosyncratic fundamentals) such that bank B suffers the same fate as bank A. Our model will, thus, hypothesise point M as that of Malaysia's case following the crisis in Thailand in 1997. By contrast, point O will be the case of Singapore, Hong Kong or Australia because these countries were immune from the contagious impact from the rest of East Asia, despite the existence of strong economic and financial links with the region.

5.4.2 Regulatory Mechanism Design - Microprudential vs Macroprudential regulations - Challenges for the IMF and Central Banks

One of the challenges awaiting policymakers such as the IMF and Central Banks, is the design of an appropriate regulatory system to ensure financial stability. A great part of the literature on banking regulation (or the design of optimal regulatory framework for banking) tends to focus on the specific means to pre-empt the likelihood of financial contagion. Whilst microprudential regulation has received much attention and theoretical support, macroprudential regulation has often been ignored in debates over the most appropriate form that a country's regulatory framework should take.

Microprudential regulation concerns all the preventive measures taken at individual bank level designed to ward off the possibility of a bank failure being transmitted to the whole banking and financial system. It consists mainly of 'one-sided' policy measures[2] either intended to protect the depositors of the bank or as a general safety net designed to maintain the confidence of all stakeholders in the banking system. Deposit insurance schemes characterise the former set. Suspension-Of-Convertibility (SOC) and Lender-Of-Last-Resort (LOLR) characterise the latter set.

In 'direct link' models of financial contagion, microprudential regulatory measures would work in pre-empting the transmission of a banking panic. Since contagious crises arise essentially because of interdependence and are transmitted through channels that remain unchanged in all states of the world (non-tranquil periods and tranquil periods), the commonly held *"Help one, Save all"* syndrome works. Microprudential measures, however, do not work effectively if the main reason for bank failure is some commonly based fundamental that links both banks. For example, as mentioned in the introductory section, suppose two banks have received financial contracts (lent) in euros and have issued financial contracts (borrowed from depositors) in dollars. A depreciation of the dollar against the euro could negatively affect the balance sheet of both banks and lead to premature withdrawals by depositors in each bank. In this case, the interbank market does not help as a liquidity reshuffling mechanism. One-sided measures do not work here either. What is needed is some policy action designed at targeting the common macroeconomic fundamental that is commonly

[2] We use the term 'one-sided' measure because we shall be assuming that the policy applies only to the bank facing the crisis. There is no randomisation among the banks (i.e good banks or bad banks) and no economy-wide safety net. Forbes and Rigobon (2001) describe these one-sided measures as isolation strategies.

driving both banks' performance e.g limit the fluctuation of the dollar against the euro by designing some form of explicit exchange rate arrangement that will achieve this goal of currency stability. In the South East Asian crisis of 1997, the banking panic throughout the region occurred because of the banks' exposure to extreme exchange rate changes, which softened their balance sheets and made them much more vulnerable and prone to bank runs. In instances such as these, macroprudential regulation should be given the overriding concern.

Microprudential regulatory measures in a one-bank setting (the current literature paradigm) still seem best at pre-empting the likelihood of a crisis from existing in one bank by effectively acting as a mechanism that coordinates the beliefs of depositors of that bank on the right equilibrium. However, in a two-bank setting with informational externalities, the mechanism implicit in the transmission process of information may create feedback effects that have repercussions on depositors of other banks. Thus, tackling a liquidity crisis at a bank (e.g Bank of England's intervention to provide assistance to Northern Rock in 2007) may have a signalling value that affects the behaviour of depositors of other banks in the UK economy, such that the liquidity assistance becomes counterproductive. The appropriate design of microprudential policy measures by a Central Bank must take into account this signal spillover effect. Clearly, solving a liquidity crisis at one bank may be sub-optimal if other depositors in the economy interpret this as a sign of panic and start worrying about the medium-term prospects of their own banks. In this case, we have a intertemporal substitution of a financial crisis across banks. A banking economy in which, say, suspension is adopted as a policy instrument at the crisis-catalyst bank, may send the wrong signals to depositors of other banks[3]. By contrast, a LOLR banking economy does better at eliminating contagious flows because the LOLR measure at one bank may send a positive or negative signal to depositors of the second bank[4]. The optimal design of microprudential measures should

[3]See Note I in the Appendix (section A.4)

[4]See Note J in the Appendix (Section A.4)

balance the contemporary positive impact of solving a liquidity-based crisis at the cost of future information-induced crisis at other banks.

If the future costs weigh more than the current benefits, does that suggest that microprudential policy measures should never be implemented ? One possible way of achieving pareto improvement will be for the Central Bank to successfully maintain confidence of depositors at a high level *across* banks, when implementing a liquidity-based prudential measure at one bank. The Northern Rock crisis of 2007 showed that this should have been the optimal response of the Bank of England in its interventionist role to achieve financial stability. Ostensibly, how to maintain confidence across banks is subject to disagreement among practitioners. While our model does not tell us about the exact form these safeguards should take, it does improve on the existing literature on (one-bank) liquidity-based policy intervention measures in that it provides a logical framework that rationalises the case for such appropriate safeguards to accompany the conventional type of policy intervention. To sum up, we have three cases that can be Pareto-Ranked:

General Corollary (Policy Intervention and Paretian Ranking) *In our model, we conjecture that microprudential liquidity-based measures administered by the Central Bank under the current paradigm, are not potent due to the presence of intertemporal substitution of a banking crisis. A superior outcome will be to accompany these liquidity-based interventionist measures by appropriate 'confidence safeguards' throughout the rest of the financial system. These confidence safeguards work as a pivotal mechanism that coordinates the expectations of depositors across banks on the right outcome by ensuring that the positive signals are sent to these other depositors in the economy. This mechanism 'Pareto improves' on the current paradigm and achieves the twinned aims of containing a crisis at a catalyst bank and of preventing intertemporal substitution. In case wrong signals are sent, these liquidity-based measures may help create a channel of financial contagion of their own. This outcome is 'Pareto inferior' to the current paradigm.*

This new implication for microprudential policy design is important, because it tells us that in sequential games with informational spillovers, there are different ways for depositors in an economy to interpret the implementation of a given liquidity-based prudential measure at a bank: instead of acting as a coordination mechanism for depositors of the same bank (as the current one-bank paradigm will warrant), these measures need to coordinate the expectations and beliefs of depositors across different banks on the correct equilibrium. For that, it is imperative that positive signals through appropriately-designed safeguards, are sent.

5.4.3 The Credit Crunch Crisis of 2007-2008 - The Special Case of Northern Rock

How relevant are our findings to the Northern Rock crisis of 2007 ?

Northern Rock, a former mutual savings and prime mortgage bank based in the UK, became a prominent casualty of the financial crisis that began to unfold in 2007. To see the relevance of our findings, we first highlight the differences between our model setup and the banking structure of Northern Rock.

According to Shin (2009), the structure of the balance sheet of Northern Rock differed from that of conventional banks in bank run models such as Diamond and Dybvig (1983). Conventional banks have a balance sheet structure characterised by maturity mismatch that we identified in our literature review of **chapter 2** i.e short-term liquid liabilities and long-term illiquid assets. The liabilities consist essentially of (branch-based) retail deposits and equity. The asset side consists of liquid cash (till cash, treasury bills, reserves held at Central Bank) and illiquid assets (investments and loans). Our modelling structure follows this conventional paradigm. However, unlike traditional banks which have a liability structure consisting mainly of retail deposits, a significant proportion of the liabilities of Northern Rock consisted mainly of wholesale deposits like securitized notes, covered bonds, interbank deposits and lending from a wide investor base that spans the globe.

According to Shin (2009), that creates an irony. How did retail depositors run on the bank? To understand this paradox, Shin (2009) provides a meticulous analysis of the subtleties of Northern Rock's financial structure and operations. We will summarise the important elements here in order to better appreciate how our paradigm, embodied in **chapters 3, 4** and **5**, can help explain what happened in Northern Rock's case.

The main elements of fragility came when the common pool of liquidity in the wholesale funding market (from which Northern Rock was relying greatly upon) began to dry up. This event began to take shape when there were a series of subprime mortgage defaults in the US and a number of European and US banks started to register losses on their Structured Investment Vehicles (SIV) - which invested in these banks' securitized assets backed by short-term debt such as Asset Backed Commercial Paper (ABCP). Northern Rock's increasing reliance of this common pool of funding, backed by ABCP, made it easily vulnerable to the unwillingness of lenders in the wholesale market to lend. This idea is similar, though not identical to our common investment story or that bank A and bank B having risky investments that are affected by the same macroeconomic fundamental. Thus, it becomes apparent that reliance on wholesale funding led to common vulnerability and had some element of correlatedness, attached to it. An important difference is that, in our model, the common exposure lies on the asset side. In the Northern Rock's case, the source of vulnerability lied on the liability side.

Unlike investment banks in Europe and in the US, Northern Rock was not engaged in subprime mortgage lending. Furthermore, as aforementioned, while US and European banks usually get their loans off their balance sheet through special conduits or SIV that hold mortgaged assets backed by short-term leverage such as ABCP, the activities of these special purpose leveraged entities were consolidated within the balance sheet of Northern Rock. Thus, a failure of lenders in the wholesale market to lend due to a tightening of their risk constraints, will directly impinge on the bank's balance sheet. Thus, the degree of exposure that Northern Rock had to these vulnerabilities in the wholesale lending market, could be re-interpreted as its idiosyncratic fundamentals. Here again, an important difference with our approach, is that our idiosyncratic fundamentals are modelled on the asset side whereas for Northern Rock, they would appear on the liability side.

Shin (2009) identifies a crucial fact about the behaviour of creditors (i.e lenders in the wholesale funding market) of Northern Rock which corroborates the behaviour of retail depositors in our paradigm. He argues that, unlike the conventional Diamond-Dybvig (1983) story, in which depositors withdraw based on their fears that others withdraw irrespective of fundamentals, those lenders who withdrew their funding in the wholesale market, did not do so by fears of others' behaviour. These lenders were sophisticated investors and acted on fundamentals. When economic conditions were good, prudent risk management policy (as well as regulatory policy) relaxed risk constraints for lenders. As a result, they could increase their lending. However, when signs of dramatic turnaround in economic conditions started to hover, risk constraints became binding and there was a general retrenchment of lending. This resulted in a drying up of the pool of funding from which Northern Rock was quenching its liquidity needs. This behaviour in lenders' behaviour suggests that, far from being a panic-based story, there was a coordinating device that coordinated behaviour of lenders in their decisions. A possible example that Shin (2009) provides is the general decline in house prices which led to a series of defaults in subprime mortgage in the US and to general de-leveraging. In our model, due to supermodularities or strategic complementarities in the payoff structure of depositors, depositors (the only source of creditors) withdraw because others withdraw. But what is coordinating the behaviour of depositors is the presence of low idiosyncratic fundamentals of the bank. Thus, like in Northern Rock, fundamentals act as coordination device for the behaviour of creditors of the bank. Unlike Northern Rock' s case though, these fundamentals inour setup, lie within our banking system itself.

A further compelling argument that shows similarity of our setup with that of Northern Rock, is that in our work, the run by depositors are a consequence of some fundamental weakness – as suggested by the presence of weak fundamentals that directly affect the banks. Bank runs are not a cause of banking failure. Shin (2009) argues that the bank run by retail depositors of Northern Rock was, in a similar way, a result of these retail depositors appraising the weaknesses faced by their bank in its difficulty in securing liquidity in the wholesale market, and anticipating its ultimate demise. He argues[5]: *"...The Northern Rock depositor run, although dramatic on television, was an event in the aftermath of the liquidity crisis at Northern Rock, rather than the event that triggered its liquidity crisis...."* (pp 102). This observation lends credence to the belief that the run by retail depositors in Northern Rock, was essentially information-based. This is similar to our setup. Our approach, by embedding the global games framework within a Diamond and Dybvig (1983) setup, has the advantage of bridging the gap between panic-based stories and information-based stories. While we can explain a bank run as a panic-based story, unlike Diamond and Dybvig (1983) who focus on extraneous variables such as sunspots as coordinating device for depositors' behaviour, we provide an endogenous explanation for behaviour of depositors: each bank's idiosyncratic fundamental acts as a coordinating device for its depositors' collective behaviour.

A crucial similarity between Northern Rock's case and our work, lies with our conjecture about policymaking. We mentioned earlier that our dynamic Bayesian approach with informational spillovers, offers fresh insights on the economics of interventionist policies implemented at a crisis-catalyst bank. These insights improve on the standard paradigm currently suggested by single-bank frameworks. One of the key insights of our approach is that depositors pay attention to the importance of public information in making decisions about whether to stay or withdraw. We conjectured through the innovative concept

[5] "Reflections on Northern Rock: The Bank Run that heralded the Global Financial Crisis", Hyun Song Shin, *Journal of Economic Perspectives* (2009), Vol 23, No. 1, pp 101-119

of *'intertemporal substitution of banking crisis'*, that any attempts to intervene at a crisis-catalyst bank through some sort of liquidity support, may be interpreted in different ways by depositors of other banks. If they interpret this public information as a sign of weakness, they may choose to withdraw from their own banks. Thus attempts to solve a crisis at one bank, through public support that galvanised media attention, have created a channel for spreading the crisis to other banks, by causing depositors in otherwise healthy banks to withdraw. In Northern Rock's case, even though the liquidity support from the Bank of England did not concern another bank, the public signal of the Bank of England's intervention, did uncover an underlying weakness about Northern Rock– which caused its retail depositors to withdraw.

In Shin's (2009) words[6], *"...On September 13, 2007, the BBC's evening television news broadcast first broke the news that Northern Rock had sought the Bank of England's support. The next morning, the Bank of England announced that it would provide emergency liquidity support. It was only after that announcement—that is, after the Central Bank had announced its intervention to support the bank—that retail depositors started queuing outside the branch offices....."* (pp 101).

Thus, to adapt our conjecture specifically to Northern Rock, lets assume that the consolidated balance sheet of Northern Rock comprises of the activities of two sub-banks: those of bank A (which deals with wholesale deposits) and those of bank B (which deals with retail deposits). Using the results of our framework, we can safely say that the public news of the intervention of the Bank of England to ward off a wholesale-based run in bank A, has created a crisis channel of its own, by inducing retail-based depositors in bank B to run on their bank. [Please turn over to next page for an illustration of this scenario in Figure 5.4(a)-(c)].

[6] "Reflections on Northern Rock: The Bank Run that heralded the Global Financial Crisis", Hyun Song Shin, *Journal of Economic Perspectives* (2009), Vol 23, No. 1, pp 101-119

FIGURE 5.4(a): Balance Sheets of Bank A and B in our Model (ignore Equity)

Bank A

Assets		Liabilities	
Safe Investment	x	Deposits (A)	xx
Risky Investment	x		
	xx		xx

Bank B

Assets		Liabilities	
Safe Investment	x	Deposits (B)	xx
Risky Investment	x		
	xx		xx

FIGURE 5.4(b): Consolidated Balance Sheets of Bank A and B in our Model

Consolidated Bank Group

Assets		Liabilities	
Safe Investment	xx	Deposits in Bank A	xx
Risky Investment	xx	Deposits in Bank B	xx
	xxxx		xxxx

FIGURE 5.4 (c): (Simplified) Balance Sheet of Northern Rock (ignore Equity)

Northern Rock

Assets		Liabilities	
Safe Investment	xx	Wholesale deposits / Funding (interbank funding, covered bonds, securitized notes)	xx
Risky Investment (including Mortgages)	xx	Retail deposits	xx
	xxxx		xxxx

Figure 5.4 (a) illustrates the balance sheets of our two banks, bank A and B. Figure 5.4 (b) shows the consolidated group balance sheet of the two banks, assuming that each is an affliate organisation of an underlying parent bank organisation. Figure 5.4 (c) shows the equivalence of our consolidated bank balance sheet with that of Northern Rock. In the consolidated balance sheet in Figure 5.4 (b), we proxy the behaviour of depositors in bank A as that of wholesale depositors (holders of interbank claims, covered bonds and securitized notes) in Northern Rock and proxy the behaviour of depositors in bank B as that of retail depositors in Northern Rock. Given common investments, the end result will replicate the balance sheet of Northern Rock - which we show in Figure 5.4 (c). Since a balance sheet is essentially an identity, we can interpret the behaviour of wholesale depositors of Northern Rock as a fundamental. Thus, a weakening of this fundamental (represented by a drying up of the wholesale liquidity pool due to, say, house price collapses), could lead retail depositors (classic depositors in a bank run story) to infer a fundamental weakness about their own bank and lead them to withdraw. The public signal that interventionist policies represent for depositors in the rest of the banking system, can also be explained. The Bank of England's prompt intervention in injecting liquidity in Northern Rock (due to non-availability of buyers for the bank) could equally have signalled a fundamental weakness about the bank to these retail depositors. The equivalence of this story in our paradigm is the Bank of England's intervention to help bank A financially. This creates a channel of contagion of its own on depositors of bank B as the public intervention is believed to 'reveal' a sign of weakness about their own banks. This is a typical example of the *'intertemporal substitution of banking crisis'* story that we developed before !

5.5 Conclusion

In this chapter, we have attempted to build a theoretical model of contagious bank runs which uses the informational spillover channel to explain the transmission of failures from one bank to another. We go beyond the interdependence paradigm of Chen (1999), Allen and Gale (2000), Dasgupta (2004) and Vaugirard (2005), by showing that, for banks with common macroeconomic exposures, a multiple bank failure will contain elements of both contagious and correlated banking failures and that these elements are indissociable from each other. The characterisation of the trigger equilibrium which we derived in **chapter 4**, enables us distinguish between the contagious and the correlated elements in probability terms. We show that, while the banks are naturally correlated in all states, contagion is an event of *'excess correlation'* in some states i.e it represents an endogenous state-contingent change in cross-bank correlation. We provide examples of empirical work (Forbes and Rigobon (2002), Pesaran and Pick (2007)) in the literature that identify the robustness involved in describing contagion as a case of excess correlation rather than of interdependence. We go further by characterising the events across banks as a function of informational attributes of depositors of both banks. In particular, we show that, if contagion exists in equilibrium, it is characterised by the existence of public informational dominance in bank B depositors' decision set. In other words, a (negative) contagion from bank A to bank B, would be one in which a failure of bank A, leads depositors of bank B to adjust their posterior beliefs of the common macroeconomic fundamental, such that bank B now fails for a larger realisation of its own fundamentals. Bank B now fails if and only if bank A fails and not otherwise. We explain the differences between our approach and that of Hellwig (2002) and of Banerjee (1992).

Distinguishing between contagion and correlation is important for any Central Bank since these concepts have different implications for policy implementation. Our ability to show the difference between these two concepts puts our framework in a good position to offer suggestions about the need to implement microprudential policy as opposed to macroprudential policy. We pioneer the important concept of the *'intertemporal substitution of banking crisis'* as possible conjecture to what may possibly happen if microprudential measures are administered at a crisis-catalyst bank when informational spillovers are present. Our paradigm thus provides an important framework for analysing the economics of policy implementation and offers a fresh insight over the suggestions, currently proposed in the literature, by single-bank models. We also use our framework to explain the 2007 crisis that plagued Northern Rock in the UK.

In **chapter 9**, we summarise the main findings of **chapters 3, 4** and **5** and make valuable propositions as to how to implement the model in practice. **Chapter 9** highlights our specific contributions to the literature, as opposed to the existing literature, and offers a critical appraisal of our model findings. Please turn over for an illustration of Figures 5.2 (b)-(d) (supplementary graphical notes for this chapter).

FIGURE 5.2 (b) : Case where State of Common Macroeconomic Fundamental is Good

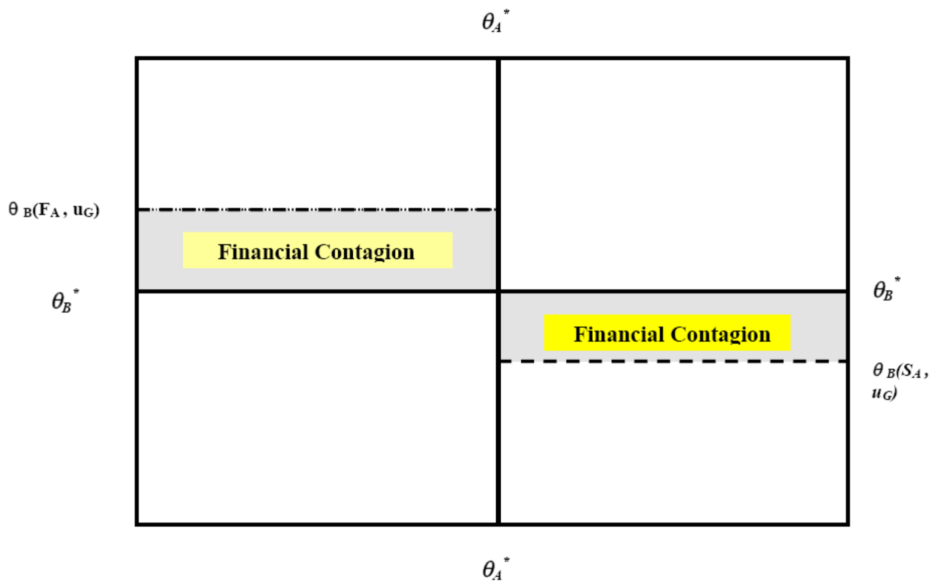


FIGURE 5.2 (c): Conditional on Macroeconomic Fundamental being Bad, Negative Contagion exceeds Negative Correlation in Probabilistic Terms

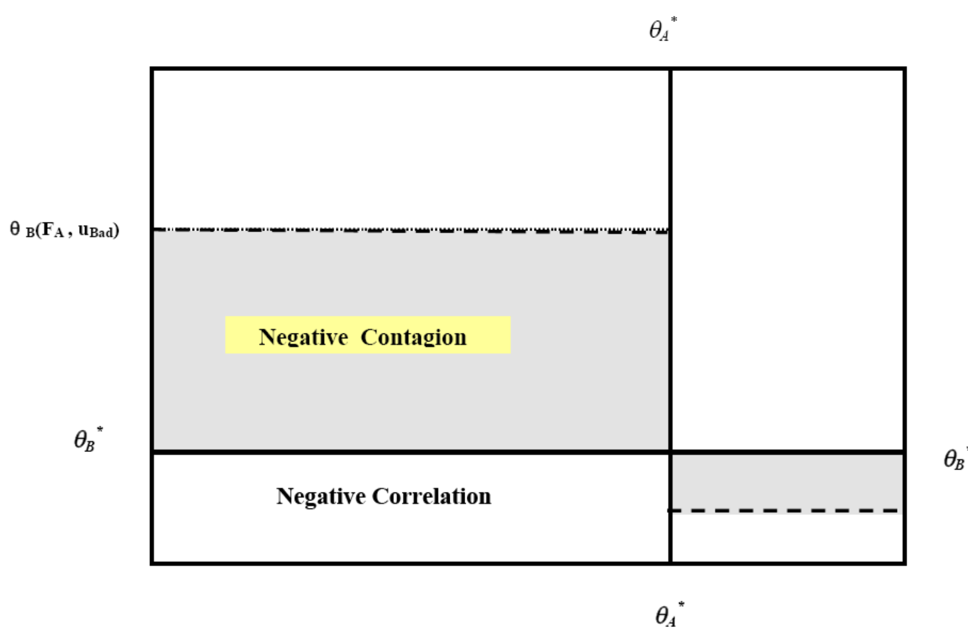
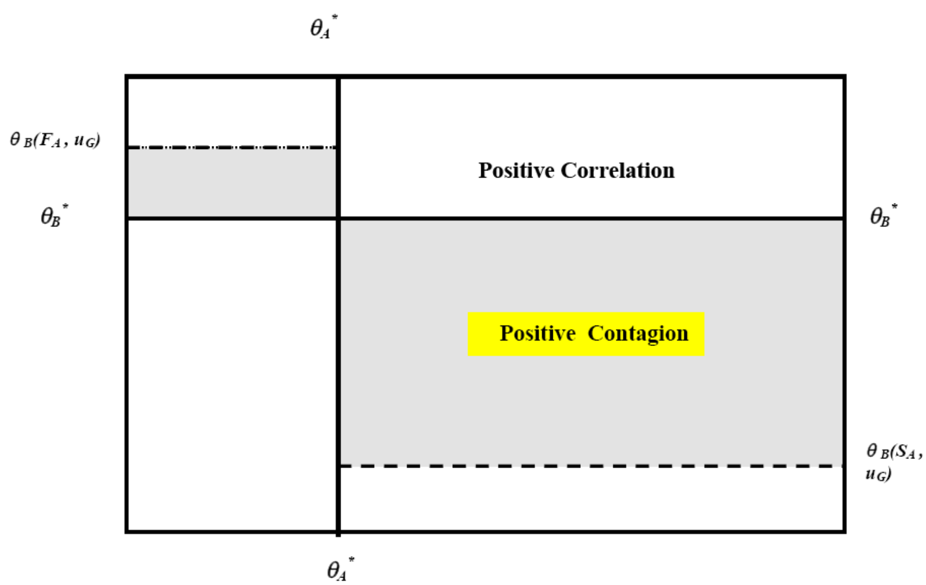


FIGURE 5.2 (d): Conditional on Macroeconomic Fundamental being Good, Positive Contagion exceeds Positive Correlation in Probabilistic Terms



Chapter 6

Financial Fragility in Emerging Markets

6.1 Introduction

In this chapter and in the next two, we will address the second main question we considered in the introduction of this thesis. As a reminder, the question we will tackle is the following: "*How can we embed a model of banking crisis within an Emerging Market Economy (EME) framework in a way that enables us to study theoretically the transmission mechanism between a banking crisis and a currency crisis ?*" In particular, we are interested in developing a theoretical model that explains two transmission conduits: the contagious flows from a banking crisis to a currency crisis and vice versa. This chapter will act as feeder to the **chapters 7** and **8**, in that we will introduce the formal environment for our banking model in this chapter. The methodological structure for each transmission mechanism (and the underlying results) will be developed in each of the next two chapters respectively.

Banking and currency crises were virtually unrelated in the 1970s when financial markets were highly regulated in industrial and developing countries alike. The old vintage literature on financial crises documented the occurrence of these crises in separate strands.

The "currency crisis" paradigm stressed on the existence of two generation-models of crises: the first generation developed by Krugman (1979) showed how inconsistent domestic macroeconomic policy can lead to an attack on the currency by rational speculators and lead to a collapse of the fixed exchange rate regime. The first generation was useful in explaining the crises of Mexico (1972-73) and Argentina (1978-81). The second generation developed by Obstfeld (1986) explained how, irrespective of the government's macroeconomic policies, shifts in market expectations can alter the government's trade-off between fixed exchange rate and other objectives (e.g domestic employment and output), thereby leading to self-fulfilling behaviour and multiple equilibria. The second generation was helpful in explaining the Exchange Rate Mechanism (ERM) crisis of 1992. While both generations of models had legitimate applications, neither was appropriate to explain the financial crashes of the Emerging Market Economies (EMEs) of the mid-1990s. In particular, in the case of the Asian crisis of 1997, fiscal stances were moderately sound and these economies were growing quickly. Instead, these financial crashes unearthed the existence of financial vulnerabilities in the form of troubled banks, contagious flows across banks and increased susceptibility of these growing economies to sudden reversals of capital flows. Neither of the first two generations incorporated the banking sector and no allowance was made whatsoever for the microfoundations of financial intermediation.

The "banking crisis" paradigm evolved separately from the currency crisis literature, to explain the role of banks in an environment in which the standard Arrow-Debreu framework does not hold. The "panic-based" story of Diamond and Dybvig (1983) stressed the existence of asymmetric information and illiquid investment and on the existence of banks as liquidity insurers by offering demand deposit contracts. Due to the lack of determinacy of beliefs, there are multiple Pareto-ordered Nash equilibria and bank runs arise potentially when the depositors collectively choose the pareto-dominated outcome, independently of the performance of their banks. This fact has been proven not to hold empirically as Gorton (1988), Calomiris and Gorton (1991) showed bank runs to be related to the business cycles that directly affect banks' performances. The "information-based" bank run story developed as a consequence, to provide a theoretical rationale for such observations, by postulating an environment in which depositors receive some information about their bank's performance. Notable contributions in this area include: Jacklin and Bhattacharya (1988) and Allen and Gale (1998, 2000a).

Financial innovations and increased integration in the global financial market in the past two decades, do appear to have introduced some new elements, so that despite some similarities, crises of recent years have differed in many important respects from those of the distant past. Prominent among the 'new' features of modern financial crises, are the contagious elements that they assume and give shape to and the interconnections between banking and currency crises. In the 1980s and early 1990s, industrial and developing countries alike, embarked in a radical program of domestic financial deregulation, with abolition of interest rate controls, relaxation of controls on bank asset types and gradual liberalisation of the domestic financial markets, topping the agenda of financial sector reforms. One consequence of such liberalisation was the unrestricted flows of capital across borders. Dermiguc-Kunt and Detragiache (1998) document the strong association that exists in emerging markets between financial liberalisation and financial fragility, with the association being stronger for economies that do not have a strong infrastructure for regulation and supervision. Chang and Velasco (1998), in a similar vain, highlight the theoretical association between increases in foreign capital (especially short-term) due to liberalisation and illiquidity of banks. A separate result of this financial globalisation was that the relationship between banking and currency crisis became more intimate. Evidence by Kaminsky and Reinhart (1998) and Schumacher (2000) points in that direction. The close association between banking and currency crises suggests that a new theoretical paradigm, deeply rooted in financial intermediation, is needed to provide an endogenous explanation to the occurrence of financial crises in an open economy context.

An analysis of the anatomy of financial crises doctrine of the 1990s, helps unearth a number of 'stylized facts' of those countries experiencing the "new generation" of financial crises:

[1] *They have a de facto pegged exchange rate regime.*

[2] *They are in receipt of substantial capital inflows, often with short-term maturity.*

[3] *These capital inflows are intermediated through the banking system.*

[4] *They have embraced economy-wide domestic financial deregulation and wider capital account liberalisation without appropriate prudential regulation and supervision.*

[5] *Bank balance sheets have assets denominated in the home currency and liabilities denominated in the foreign currency - these balance sheets are unhedged against foreign exchange risks.*

[6] *There is an explicit form of governmental guarantee or insurance of financial losses, that creates some form of moral hazard (implicit form of hidden government debt).*

We focus on an EME in this chapter and in the following two. Technically an emerging market may either be a developing country with substantial inflows of capital from abroad (i.e satisfies [1] -[5] above) and boasts of an improved domestic financial sector (relative to financial repression) or an economy which is in transition from a centrally planned system to free market capitalism and which faces moral hazard issues in the first stages of the transition process (i.e satisfies [6] predominantly). The material contained in this chapter departs radically from the paradigm developed in the previous chapters in that we construct a banking environment that considers the specificities of emerging market economies (satisfying [1] -[5] above). It is our intention in this chapter (and in the following two) to analyse how the complexities of emerging market economies may affect the operation of an open-economy banking system where banks are modelled a-la Allen and Gale (1998) as deposit-taking institutions.

One of the main features of banking models developed in the literature[1] is that they are developed without taking into account the specific nature of the market structure or level of economic development of the economy in which the banks operate. The existing literature on banking models has been more inclined to consider informational or contractual aspects related to banking crises. From the seminal work of Diamond and Dybvig (1983), research has inexorably been bifurcated into theoretical work that gives attention to either aspect: either by highlighting ways of getting rid of equilibria multiplicity through noisy informational processes that act as coordination devices for depositors' beliefs (Allen and Gale (1998), (2000), (2004), Goldstein and Pauzner (2005), Dasgupta (2004), Morris and Shin (2000)) or by focusing on variants of demand deposit contractual arrangements (Green and Lin (2003), Peck and Shell (2003), Goldstein and Pauzner (2005)) and determining how these variants affect a deposit contract as a risk-sharing tool. Existing literature work does not address the pivotal issue of the nature of the economic system in which banks operate and how this specificity affects the ability of banks to fulfil their roles. Clearly, a banking crisis in a developing country carries symptoms that differ radically from that which occurs in a developed economy. The level of economic development is ostensibly considered to be exogenous to the banking system of these economies. Nonetheless, they do have none trivial implications on the ability of banks to perform their maturity-transformation and liquidity insurance provider roles. Thus, the nature of an economic system and its level of development impose a number of exogenous macroeconomic constraints on banks. How these exogenous macroeconomic constraints affect banking systems and the resulting anatomy of financial crises, is the treatise of this chapter and **chapters 7** and **8**.

One of the appealing features of our paradigm is that it brings to the fore-

[1] Refer to **chapter 2** for a review of all key models.

front, new issues that have, hitherto, not been discussed in the literature. A prominent element of research that ceremoniously makes its appearance, is the relationship between banking crises and currency crises. Whilst the literature is replete with empirical papers that document the relationship, theoretical work is still at its embryonic stage. Chang and Velasco (2000a) try to study the nature of equilibrium (uniqueness or multiple equilibria) in an open economy banking system, under different exchange rate regimes. Important differences with our work[2] are that they do not study the exact cause-effect relationship from one type of crisis to another. In our setup, by getting rid of multiplicity of equilibria, we can study the exact nature of causation by endogenising the probability of events. Furthermore, Chang and Velasco (2000a) do not deal with banks characterised by liability dollarisation whereas our setup incorporates banks characterised by liability dollarisation. Finally, we can analyse the welfare properties of specific policy measures. Chang and Velasco (2000a) do not discuss effectiveness of policy due to indeterminacy of outcome in their setup. To our knowledge, there is no theoretical paper that unearths the exact nature of the transmission mechanism between banking and currency crises, taking as backdrop the exogenous macroeconomic constraints or level of economic development of that country. Our work, embodied by our separate contributions inherent in **chapters 7** and **8** (which both build on the environment we consider in this chapter), is intended to bridge that gap.

Section 6.2 introduces the formal environment of our setup, which we will develop further in **chapters 7** and **8**. **Section 6.3** concludes.

Synopsis of our Theoretical Paradigm We consider an open economy version of a banking model developed by Allen and Gale (1998). There are two currencies: pesos (the home currency) and dollars (the foreign currency) and three time periods: $t = 0, 1, 2$. All consumers are foreign investors who are

[2]Refer to Table 1.2 in **chapter 1**.

endowed with 1 dollar each. They deposit their endowment of 1 dollar at the bank. The bank is modelled as a mechanism that accepts deposits of dollars from foreign investors and proceeds to convert these dollars into pesos at the Central Bank and to invest some of these pesos in a safe storage asset (that yields a return of 1 unit in period $t+1$ for each unit invested in period t). The bank then invests the resulting pesos in a long asset that yields a return of R (> 1) in period $t = 2$ for every unit invested in period $t = 0$. The long asset can be liquidated in the intermediate period at a loss. One may think of the long asset as a non-tradable good (e.g the housing sector, for instance), whose returns are denominated in pesos. Since we are considering an EME with lack of financial sophistication and characterised by the absence of a financial market other than the banking system, it is assumed that, in the eyes of foreign investors, the economy lacks credibility to offering debt / deposit contracts denominated in pesos. As a result, all deposit contracts are stipulated in dollars. The bank's problem is to choose a risk-sharing contractual agreement that maximises the expected utility of depositors subject to a zero-profit constraint . It decides on the optimal portfolio between short and long asset in period $t = 0$.

By encompassing features $[1] - [5]$, there are two main sources of financial vulnerabilities in our setup: there is an *asset-liability maturity mismatch*[3] as in all bank run models - Bank liabilities (deposits) are essentially short-term in nature and liquid while the bank asset (the long asset) is illiquid, with the added feature that there is an inverse relationship between liquidity and viability on the bank's asset portfolio. A new extension that we provide to Allen and Gale (1998) is that there is also an *asset-liability currency mismatch* in that, while the main assets are denominated in pesos, all its liabilities are denominated in dollars[4]. Thus, as foreign investors will face a liquidity preference shock, they

[3] The composition of capital inflows was an important factor in a number of financial crises in many EMEs, such as in Thailand in 1997/8 and in Mexico in 1994/5. In both cases, reliance on short-term borrowings to finance huge current account deficits, was the linchpin of financial crises.

[4] It is ostensible that a portfolio choice (i.e the share of wealth held in pesos and in dollar-

will withdraw from the bank in period $t = 1$ (if they are impatient consumers) or in period $t = 2$ (if they are patient). In either case, the bank promises to meet their contractual obligations in dollars. The two sources of financial vulnerabilities arise because at the time of investment and decision on optimal portfolio choice, they are zero-probability events. It is in period $t = 1$ that depositors know their types and that the precise nature of aggregate uncertainty in the model becomes known.

In adopting this modelling structure, our aim is twofold. First, we want to highlight the nature of the transmission mechanism from a banking crisis to a currency crisis (and vice versa) and to analyse the necessary and sufficient conditions for such a transmission process to occur. Second, we want to shed light on the debate on the most appropriate form of the exchange rate regime and the accompanying safeguards that may be adopted by an EME - where the appropriate form of the exchange rate regime is the one that minimises the probability of either form of crisis.

In general, the literature on banking panic transmission in an open economy context has taken off mainly on the empirical side with contributions from Kaminsky and Reinhart (1999). The existing literature shows that a banking crisis[5] may lead to a currency crisis when depositors running on the bank go to the Central Bank to exchange their home-currency deposits for foreign currency - the Central Bank loses reserves in the process, which makes it more likely that a currency crisis will prevail. Since we assume that deposits are denominated in dollars, this possibility will not arise in our setup; alternatively, resolving a

denominated bonds) depends on the risk-return characteristics of these securities, the structure of shocks and on monetary and exchange rate policies. In our modelling of an EME, we shall assume that *all* deposits are in dollars and *all* assets are in pesos. Thus, the choice of the currency denomination of our asset portfolio is taken as exogeneous in our setup.

[5] In this paper, any attempt to run on the bank is a case of "capital flow reversal". We may occasionally use the terms bank runs and capital flow reversals interchangeably.

banking crisis by the use of explicit governmental bailouts (e.g Lender-of-Last-Resort (LOLR)) requires the use of Central Bank reserves: a Central Bank that uses reserves to defend a peg and to bailout illiquid banks, runs the risk of generating a currency crisis. A currency crisis may cause a banking crisis through the effects of a currency devaluation on the balance sheets of banks characterised by liability dollarisation. Resolving a currency crisis may, by itself, lead to trouble in the banking sector if it requires massive interest rate hikes which weaken banks by inducing adverse selection and moral hazard in their asset portfolio. Alternatively, a banking crisis and a currency crisis may have some common exogenous source (e.g a recession). It is our aim to investigate the exact nature of such relationships in **chapters 7** and **8,** based on the open-economy banking environment we develop in this chapter.

6.2 The Model

6.2.1 Banking System

The economy consists of a small open financial system with an international monetary sector. There are three periods, $t = 0, 1, 2$. At the end of period 2, the experiment stops and it is assumed that all agents in the economy (consumers and institutions alike) do not exist. In the spirit of Chang and Velasco (2000a), there are two main currencies, pesos (the "home" currency) and dollars (the "foreign" currency). The financial infrastructure comprises a system of commercial banks (or financial intermediaries), a Central Bank and a foreign exchange market. There is no financial market in our setup. Commercial banks are assumed to operate in a perfectly competitive market structure.

The financial system is liberalised and foreign investors are allowed to invest in home banks. There is a continuum of foreign agents[6] in period $t = 0$, each endowed with 1 dollar. As in the literature of bank runs, the set of depositors can be represented by a unit interval $[0, 1]$, with measure equal to one and the fraction of agents in any subset is represented by its Lebesgue measure. The endowment of 1 dollar can either be consumed or invested. Agents face a privately observed uninsurable liquidity preference shock, modelled à-la Diamond and Dybvig (1983) and may be of two types: impatient agents (i.e those deriving utility solely from consumption in period $t = 1$, $u(c_1)$) or patient agents (i.e those deriving utility solely from consumption in period $t = 2$, $u(c_2)$). Agents derive utility from consuming in dollars only. We will assume that, in each region, a fraction λ of consumers is impatient and a fraction $1 - \lambda$ is patient. The probability distribution associated with consumer types, is assumed to be common knowledge and there is no aggregate uncertainty about liquidity shocks. Agents will know their types at the beginning of period $t = 1$. The utility functions that agents face satisfy the assumptions of strict concavity and being twice continuously differentiable: $u'(.) \geq 0$, $u''(.) \leq 0$ as well as the Inada conditions: $u'(0) = \infty$ and $u'(\infty) = 0$.

There are two investment technologies available, both denominated in pesos: a short-term storage technology and a long-term technology. The storage technology transforms 1 unit invested at time t into 1 unit at time $t + 1$. The long technology represents some investment in the non-tradable goods sector (e.g the housing market) and yields returns exclusively in pesos. It transforms 1 unit at time $t = 0$ into an amount R measured in pesos, in period $t = 2$. If liquidated prematurely, the long technology yields, γR ($< R$), $\gamma < 1$. Parameter γ is an exogenous element that captures the costs of early liquidation.

Agents form coalitions known as "commercial banks" in order to insure against liquidity risks. Commercial banks are assumed to be maturity transformers, whose task is to insure against liquidity preference shocks by transform-

[6] We assume that there are no home depositors. Thus, foreign depositors bring capital into the financial system in the form of deposits, which have short-term maturity.

ing highly illiquid asset-payoff streams into more liquid liability payoffs. They do this by accepting deposits of money from foreign agents, pool these resources collectively and invest in the two technologies described above[7]. In return for taking their endowments, banks compete with each other in offering demand deposit contracts to depositors. These demand deposit contracts specify the term structure of deposit payments, c_1 dollars in period $t = 1$ and $\tilde{c}_2$ dollars in period $t = 2$, according to the type of preference that the investor reports to the bank. The banks then go to the Central Bank and exchange these dollars for pesos[8], which they use to invest in the short and long technologies. Because of no aggregate uncertainty regarding liquidity preference shocks, banks choose their portfolio strategy in period $t = 0$, and invest a fraction κ in the safe technology and $1 - \kappa$ in the risky technology. We shall assume that, since the banking system is a fractional reserve system, assets in the safe technology can be viewed as reserves held at the Central Bank and that can be called-in at short notice costlessly[9].

[7] Commercial banks are assumed to have a comparative advantage over agents in investing in the two types of technologies. Furthermore, since there is no other domestic storage possibility for agents, it is assumed that all agents must deposit their money in the bank in period $t = 0$. Thus, banks implicitly satisfy participation constraints.

[8] The central bank owns the printing press and can print pesos costlessly. We assume that any printing of pesos is done at the beginning of the experiment (i.e period t = 0) only when the commercial bank deposits the depositors' endowment of 1 dollar at the central bank.

[9] The reserve requirement of this banking system is thus κ. We assume that the relationship between λ, κ and γ is as follows: $\frac{\kappa}{1-\kappa} \geq \frac{\lambda}{1-\lambda}(\gamma R)$ and that $\lambda \leq \frac{2\kappa}{1+\kappa}$. Thus, from condition $\frac{\kappa}{1-\kappa} \geq \frac{\lambda}{1-\lambda}(\gamma R)$, it follows that R has an upper bound: $\frac{\kappa(1-\lambda)}{\gamma\lambda(1-\kappa)}$ $(= R_{\max})$. In a later section, we shall show that this condition can be endogenously derived and holds the key to many results in this paper.

6.2.2 Foreign Exchange Market

In addition to its role as a liquidity insurer to foreign depositors and maturity (and currency) transformer of streams of payments, the commercial banks exchange pesos for dollars at the Central Bank in periods $t = 1$ and $t = 2$ in order to fulfill their promise of repayment to depositors in dollars. The price of the consumer good is assumed to be fixed at 1 dollar in the international market. The home price at time t is assumed to be p_t. Thus, given absolute purchasing power parity, the exchange rate at time t is given by[10] $e_t = p_t$. The exchange rate (defined as pesos per unit of dollar) of pesos for dollars is initially assumed to be[11]: 1 : 1. The exact notion of a currency crisis will be dealt in a later section when we formally introduce the concepts of international liquidity of the economy and discuss in details the mechanics of the transmission mechanism.

6.2.3 Central Bank

The role of the Central Bank is to ensure financial stability (i.e promote the safety, soundness and stability of the banking system through the design of appropriate safeguard facilities (e.g Lender-Of-Last-Resort (LOLR)) for banks in trouble where the exchange rate regime permits and by enforcing the reserve requirement policy of the fractional system. The bank is also responsible for ensuring monetary stability through the appropriate design of monetary policy. Depending on the appropriate exchange rate regime, the Central Bank is expected to carry out operations in the foreign exchange markets to safeguard the rate at which pesos trade for dollars (according to the aforementioned rule). We will be assuming, throughout this chapter and the subsequent two, that the reserve component of the Central Bank consists of dollars only and that

[10] Thus, an initial exchange rate of 1 (i.e $e_t = 1$) implicitly implies that $p_t = 1$ since $p_t^* = 1$.

[11] We assume that any fixed rate is overvalued so that breaking away from the straightjacket of a peg, means that the currency will be devalued (i.e $e > 1$).

no gold or Special Drawing Rights (SDR) or any other foreign currencies exist. Furthermore, the Central Bank is credit constrained in that it cannot borrow state-contingent loans from external agencies against future reserves. This may be due to credit rationing in the international financial market or due to the risk of repudiation[12]. However, in the fulfilment of its duties, the Central Bank can sell dollar reserves in the international financial market and buy pesos at the prevailing exchange rate.

6.2.4 Timeline of Events

[PLEASE TURN OVER FOR AN ILLUSTRATION]

[12]Under credit constraint, there is policy conflict arising from the need to maintain the peg and the implicit guarantees associated with a fixed exchange rate regime.

[1] Financial System is liberalised

Period t = 0

[2] Foreign investors deposit their endowment of 1 dollar in the bank, in return for a demand deposit contract that promises to pay them in dollars

[3] The commercial bank decides on the optimal portfolio allocation

[4] The commercial bank exchanges dollars for pesos at the Central Bank at a fixed exchange rate of 1:1

[5] The bank invests resulting pesos in the safe technology and in long technology

Period t = 1

[6] Depositors learn their types and receive a perfect signal of their bank's performance that will prevail in period t = 2

[7] Depositors queue up at the bank in order to demand repayment of their deposits

[8] The commercial bank negotiates with the Central Bank for the exchange of pesos for dollars in the foreign exchange market at the prevailing exchange rate (**Ist Round**)

[9] Those depositors who demand repayment will be paid in dollars on a First-Come-First-Served (FCFS) basis

Period t = 2

[10] Depositors who have chosen to stay in the bank, demand repayment in dollars

[11] Banks negotiate with the central bank for the exchange of pesos for dollars out of remaining asset proceeds in the foreign exchange market at the prevailing exchange rate (**2nd Round**)

[12] These depositors are paid on a pro-rata basis

6.3 Conclusion

In this chapter, we have endeavoured to construct an open-economy banking system which faces a number of exogenous macroeconomic constraints that exist due to the level of economic development of the country. We began this chapter by highlighting a major lacuna in the existing theoretical literature in that there is hardly any work documenting how sensitive the banking system is to the level of economic development of that country. For this sake, we embed the Allen and Gale (1998) banking system within a Chang and Velasco (2000a) set-up but we calibrate the resulting financial system to one that takes into account the subtleties of emerging market economies. For the latter's sake, we assume that the exchange rate regime is a soft peg and that all short term foreign capital are intermediated through the banking system as deposits (i.e the banking system is well integrated in the global capital market)and that banks are engaged in liability dollarization (i.e contracting demand deposit debt in a foreign currency but holding assets in home currency). In addition, we assume that there is no ex-ante regulation of the system. The novelty of this paradigm is that it puts us in a good position to consider the dynamics of the interaction between banking systems and emerging market complexities and how these realities affect banks' role as liquidity insurance providers, maturity and currency transformers. A resulting attribute is that the anatomy of financial crises can be dissected and may thus yield interesting insights that cannot be obtained when the level of economic development is not accounted for. Our theoretical approach has the virtue of enabling us to gauge the shape of any regulatory measures that may be taken to limit the occurrence of the twin crises. Our set-up also explicates on the mechanics of the transmission process between a banking crisis and a currency crisis. **Chapter 7** will analyse the transmission of a crisis from banks to foreign exchange markets. **Chapter 8** will document the causation process from a currency crisis to a banking crisis.

Chapter 7

Information-Induced Banking Failures

7.1 Introduction

We build on the open-economy banking environment considered in **chapter 5** and consider the risk-sharing allocation of the banking system and the resulting characteristics of bank runs in emerging market economies.

As a reminder, there are two currencies: pesos (the home currency) and dollars (the foreign currency) and three time periods: $t = 0, 1, 2$. All consumers are foreign investors who are endowed with 1 dollar each. They deposit their endowment of 1dollar at the bank. The bank is modelled as a mechanism that accepts deposits of dollars from foreign investors and proceeds to convert these dollars into pesos at the Central Bank and to invest some of these pesos in a safe storage asset (that yields a return of 1 unit in period $t + 1$ for each unit invested in period t). The bank then invests the remaining pesos in a long asset that yields a return of R (> 1) in period $t = 2$ for every unit invested in period $t = 0$. The long asset can be liquidated in the intermediate period at a loss. One may think of the long asset as a non-tradable good (e.g the housing sector, for instance), whose returns are denominated in pesos. Since we are considering an EME with lack of financial sophistication and characterised by the absence of a financial market other than the banking system, it is assumed that, in the eyes of foreign investors, the economy lacks credibility to offering debt or demand deposit contracts denominated in pesos. As a result, all deposit contracts are stipulated in dollars. The bank's problem is to choose a risk-sharing contractual agreement that maximises the expected utility of depositors subject to a zero-profit constraint . It decides on the optimal portfolio between short and long asset in period $t = 0$.

By encompassing features [1]-[5] as explained in **chapter 5**, our approach enables us to highlight two main sources of financial vulnerabilities that affect the banking system: there is an *asset-liability maturity mismatch*[1] as in all bank run models - Bank liabilities (deposits) are essentially short-term in nature and liquid while the bank asset (the long asset) is illiquid, with the added feature that there is an inverse relationship between liquidity and viability on the bank's asset portfolio. What is new to the literature from a bank balance sheet perspective, is that there is also an *asset-liability currency mismatch* in that, while the main assets are denominated in pesos, all its liabilities are denominated in dollars[2]. Thus, as foreign investors will face a liquidity preference shock, they will withdraw from the bank in period $t = 1$ (if they are impatient consumers) or in period $t = 2$ (if they are patient). In either case, the bank promises to meet their contractual obligations in dollars. The two sources of financial vulnerabilities arise because at the time of investment and decision on optimal

[1] The composition of capital inflows was an important factor in a number of financial crises in many EMEs, such as in Thailand in 1997/8 and in Mexico in 1994/5. In both cases, reliance on short-term borrowings to finance huge current account deficits, was the linchpin of financial crises.

[2] It is ostensible that a portfolio choice (i.e the share of wealth held in pesos and in dollar-denominated bonds) depends on the risk-return characteristics of these securities, the structure of shocks and on monetary and exchange rate policies. In our modelling of an EME, we shall assume that *all* deposits are in dollars and *all* assets are in pesos. Thus, the choice of the currency denomination of our asset portfolio is taken as exogenous in our setup.

portfolio choice, they are zero-probability events. It is in period $t = 1$ that depositors know their types and that the precise nature of aggregate uncertainty in the model becomes known.

How do we model the banking environment ? We assume that the Central Bank, commercial banks and the foreign exchange market act as collective mechanisms designed to implement optimal allocation of resources and liquidity. The mechanism design approach yields a number of interesting results that have, so far, not been discussed in the literature of open-economy banking environments. An important theoretical result that we get is the existence of a pecking order in the ability of various mechanisms to implement optimal allocation. We first study as mechanism, the allocation implemented by the Central Bank as a Planner, with the assumption that the Planner can observe the stochastic fundamentals of the banking system. The resulting allocation is First-Best in that the Planner can effectively insure against all liquidity risks and aggregate risks in the financial system. The term structure of demand deposit payments to depoistors is non-contingent. We next analyse the Planner under the assumption that it cannot observe the stochastic fundamentals of the economy. We show that the best that the planner can do in this case, is to offer an approximate incentive-compatible mechanism that implements the Second-Best solution. Here, the Planner can only insure against liquidity risks but not against aggregate risks. As a result, the term structure of demand deposit payments to depositors becomes state-contingent i.e contingent on the realisations of the idiosyncratic fundamental of the banking system. We then move on to analyse the case for a decentralised banking system such as the one described in **chapter 5**. We show that the banking system is weakly inferior to the Planner under the second best allocation. With banking allocation, there is a positive probability that banking failures may occur. We show this by deriving the existence of a unique equilibrium in the bank's idiosyncratic fundamental, below which it is dominant for depositors to withdraw (the bank fails) and above which depositors stay (the bank succeeds). When banking failures are prevented, the banking allocation replicates that of the Planner under the Second-Best solution. Conversely, if banking failures occur, the banking allocation results in an outcome that is strictly Pareto inferior to that of the Planner. An interesting feature of this approach is that it enables us measure the success of any policy measures designed to prevent banking failures, in welfare theoretic terms. In particular, we are equipped to measure the effectiveness of various policy measures in their ability to restore the Planner's second best solution.

Another important result and contribution that we make is that under the outcome of banking failures, different sub-category of allocations can result, depending on the order in which depositors present themselves to the bank. When banking failures occur with positive probability, we show a bank run as a consistent equilibrium feature that occurs when depositors receive a precise bad interim information about bank fundamentals and they all run on the bank in the intermediate period, which is forced to liquidate its asset at a loss. Since we assume a Sequential Service Constraint (SSC), we show that there are different categories of bank runs, each of which can be Pareto ranked on the basis of the order in which depositors present themselves to the bank. In particular, a case in which a run occurs but those who are first in the queue are the impatient depositors, can be shown to result in lower welfare losses than a case in which a run occurs and those who are first in the queue are patient depositors. The latter case involves complete denial of liquidity to impatient depositors in addition to involving long asset liquidation.

In adopting this modelling structure, our aim is twofold. First, we want to extol on the nature of transmission process from a banking crisis to a currency crisis and to analyse the necessary and sufficient conditions under which a crisis will contagiously spread from the banking sector to the foreign exchange sector. Second, we want to shed light on the debate on the most appropriate form of the exchange rate regime and the accompanying safeguards that may be adopted by an EME - where the appropriate form of the exchange rate regime is the one that minimises the probability of either form of crisis. An important benchmark against which we measure the effectiveness of policy measures is on their ability to help restore the Planner's Secon-Best solution. This, by itself, constitutes an improvement over Chang and Velasco (2000a) whose multiple equilibria approach prevents them from undertaking any welfare-theoretic analysis of policy issues.

Our analysis of the transmission mechanism takes place in a state of the world in which banking failures occur in the banking system allocation. We show that a bank run can lead to a currency crisis if and only if there is intervention in the form of Lender-of-Last-Resort (LOLR), financed out of Central Bank reserves. This departs radically from the existing literature which focuses on banks in a closed economy context and which suggests that LOLR is always helpful in preserving banks' assets in a crisis. We conjecture that in the context of an EME, LOLR may be sub-optimal even it it succeeds in preserving the value of assets at the crisis-catalyst bank. In particular, we show that any attempt to solve an information-based bank run by earmarking LOLR funds (that prevents the bank from liquidating its long asset) will have a negative externality on the economy's international liquidity position by depleting the level of foreign exchange reserves. In a multi-period setting with multiple banks, we conjecture that this results in a currency crisis and may eventually lead to balance sheet effects and to a (future) devaluation-induced bank runs across other identical banks in the economy. Thus at the cost of preventing an information-induced crisis at one bank, LOLR may end up creating devaluation-induced banking failures elsewhere in the economy. This phenomenon is a completely new contribution to the literature and is what we dub, the '*intertemporal substitution of banking crisis'*, and is a conjecture which we considered in **chapter 4** within a closed-economy context.

How does our approach differ from other work in the existing literature ? In the existing literature, Kaminsky and Reinhart (1999) and Chang and Velasco (2000a) show that a banking crisis[3] may lead to a currency crisis when depositors running on the bank go to the Central Bank to exchange their home-currency deposits for foreign currency - the Central Bank loses reserves in the process, which makes it more likely that a currency crisis will prevail. In these papers, bank deposits are denominated in home currency. Since we assume that deposits are themselves denominated in dollars (which represents an important departure from the aforementioned two papers), this possibility will not arise in our setup. The theoretical literature lacks a convincing explanation for the various channels through which LOLR may create a currency crisis. Kaminsky and Reinhart (1999) conjectured that resolving a banking crisis by the use of explicit governmental bailouts (e.g Lender-of-Last-Resort (LOLR)) requires the use of Central Bank reserves: a Central Bank that uses reserves to defend a peg and to bailout illiquid banks, runs the risk of generating a currency crisis. However, this channel was not formally developed in a theoretical model. Our contribution in this respect, is meant to become a theoretical adaptation of Kaminsky and Reinhart's (1999) idea. By endeavouring to formalise the concept in a theoretical model, our approach enables us come across new interesting welfare results of sub-optimality of LOLR through intertemporal substitution of banking crisis - these results are completely new to the literature and offer a fresh insight into the dynamics of Central Bank finance in EMEs characterised by liability dollarisation.

The rest of the chapter is organised as follows: **Section 7.2** considers the system of banks, Central Bank and foreign exchange market as a collective mechanism designed to result in efficient liquidity provision. We characterise the first-best allocation of the planner and show the planner provides insurance against both, liquidity and aggregate risks. The second-best allocation of the planner, however, hedges against liquidity risks only. We move on to show a banking economy replicates the second-best allocation of the planner when

[3]In this paper, any attempt to run on the bank is a case of "capital flow reversal". We may occasionally use the terms bank runs and capital flow reversals interchangeably.

depositors receive a signal which is above the equilibrium threshold. When banking crises occur (i.e when depositors receive a signal below the equilibrium threshold), the banking allocation results in a Pareto-inferior allocation to the second-best allocation of the planner. **Section 7.3** analyses the dynamics of financial fragility in our setup. We show that, with no LOLR, the Central Bank always has foreign currency reserves to meet demand for deposit withdrawals during episodes of banking crises. Thus, there is no spillover to the foreign exchange sector. In the presence of LOLR designed to solve an information-induced banking failure, a crisis may spillover to the foreign exchange sector under certain parametric assumptions. It is the purpose of that section to explicate on these parametric restrictions. **Section 7.4** considers some applications of our paradigm - in particular, we conjecture the existence of intertemporal substitution of banking crisis in an extension of our model to a multi-bank, multi-period setting. Finally, **section 7.5** concludes.

7.2 Mechanism Design Problem for an EME

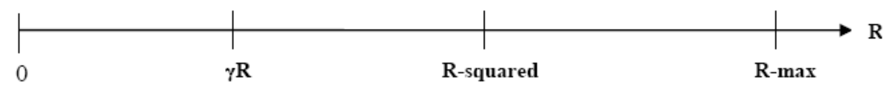
We explore the causality linkages between a banking crisis and a currency crisis and starts with the assumption that the exchange rate regime is a soft peg. The nature of aggregate uncertainty concerns the risky asset returns, for which the foreign depositors receive a precise signal in period $t = 1$. One may think of stochastic variations in the bank's long asset returns as changes in global macroeconomic factors that may impinge on the bank's performance e.g structure of their financial systems, global market conditions (terms-of-trade or global interest rates)[4] and exchange rate misalignments[5]. We first develop two mechanisms that act as a useful welfare theoretic yardstick against which the banking implementation can be compared. We study the Central Bank as a Planner under the assumption that it can observe all stochastic fundamentals of the economy and under the assumption that it cannot do so. So-doing will enable us contrast the optimality of liquidity implementation in our banking environment. If

[4] The importance of *global market conditions* has been highlighted by Calvo, Leidermann and Reinhart (1993). In particular, the banking systems of EMEs have become more sensitive to fluctuations in the **terms-of-trade**, to **global interest rates** and to **reversals of current account deficits.** On a separate note: [1] **Terms-of-Trade** affects the performance of the export industries and, with this, the loan performance of banks that have lent to these industries; [2] Increases in the **global interest rates** make it harder for EMEs to pay their external debt and aggravates the adverse selection and moral hazard problems in banks' loans portfolios. Declines in such rates increase the ability to pay external debt but, by increasing the flow of capital towards EMEs, puts upwards pressure on the real exchange rate and aggravate their current account. Since we argued earlier that the bank's long asset may be a non-tradable good like the housing sector, a good example of how it may be affected by global economic conditions can be provided by the US banking system and China's pegged exchange rate policy. Many US banks have investment portfolios in the housing sector. Most economists agree that China's policy of pegging its currency to the dollar is benign to the US housing market because it keeps interest rate low in the US. A revaluation policy of the Chinese currency, if significant, may drag up US interest rates and adversely affect the US banking system portfolio by bursting house price bubbles; [3] **Reversal of a current account deficit** may, by itself, engender a financial system fragility for an emerging market economy in that it may require a currency devaluation, which induces balance sheet effects for banks engaged in liability dollarisation. Alternatively, such reversals may require a significant drop in output (lower home demand for tradable and non-tradable goods) and a decrease in price of non-tradables. If banks have lent to the non-tradable sector, a decrease in the price of the latter may lead to fragility and to non-performing loans.

Away from the developed world, the incidence of banking crises in many EMEs is systemically related to global financial conditions.

[5] Since the bulk of international trade and finance is carried out in the monies of rich industrial nations, many EMEs have an interest in how currency fluctuates between these nations.

FIGURE 7.1 : Parametric Restrictions



- For any values of **R** lying between 0 and **R-max**, it follows that **γR** lies between 0 and **R-squared**
- As **R** approaches **R-max**, **γR** approaches **R-squared**. As **R** approaches 0, **γR** approaches 0.

banking crises occur under the banking environment, an interesting feature of the mechanism design approach that we develop is that it enables us characterise the welfare properties of different policies designed to tackle the banking failure. We measure the effectiveness of different policy measures by their ability to restore the optimal allocation of the Planner.

Bearing in mind the timeline of events as highlighted in the previous section, we assume that, at the beginning of period $t = 1$, all depositors receive a perfect signal of the bank's portfolio performance. The signal structure is modelled à-la Allen and Gale (1998) and is $s = R$ in case the news concern the bank's portfolio performance. R is stochastic, with probability density function $f\left(\tilde{R}\right)$, where $0 \leq R \leq \frac{\kappa(1-\lambda)}{\gamma\lambda(1-\kappa)})$ and we will assume the exchange rate to be fixed initially. There is a sequential decision rule and in period $t = 1$, agents line up at their banks demanding repayment of their deposits in a "First-Come-First-Serve" (FCFS) basis. When it comes to receiving payments in period $t = 2$, the remaining agents share the value of the remaining assets on a pro-rata basis (with maximum serving of $\tilde{c}_2$ dollars).

Assume that the Central Bank, commercial banks and the foreign exchange market act as a collective mechanism designed to implement the Pareto optimal allocation of resources. Since the interim information concerns only the bank portfolio performance, we will start with the assumption of a standard fixed exchange rate regime, defined as follows:

Definition 7.1: (**Fixed Exchange Rate Regime for an EME (Soft Peg**[6]**)**) *A monetary arrangement in which:*

[1] *The Central Bank is willing to engage in foreign exchange market in order to maintain the parity between pesos and dollars, so long as foreign exchange reserves are positive.*

[2] *The Central Bank can engage in providing emergency liquidity assistance to banks in trouble through its Lender-of-Last-Resort (LOLR) facility.*

[3] *There is no inflation adjustment mechanism, as long as the soft peg is maintained. Monetary policy is determined by the assets available in the banking system, rather than by liquidity needs of deposit payments. The liabilities of the banking system represent implicit obligations in the international currency.*

[4] *There is no one-to-one relationship between changes in the volume of pesos in public circulation and changes in the volume of dollars in the reserves of the Central Bank.*

7.2.1 First-Best Allocation (Central Bank acts as Social Planner)

Consider a fully centralised case in which the Central Bank, as planner, observes all the economic variables and can costlessly rehuffle resources within the banking system and across time and states of nature. The planner aims to maximise the expected utility of a (representative) foreign depositor by means of a feasible mechanism. We shall assume that, due to ex-ante homogeneity of foreign depositors, the planner restricts attention on feasible direct mechanisms

[6] The term "Soft Peg" is used because the exchange rate of pesos is fixed in value to the dollar, with some commitment for the central bank to defend it but with the value likely to change if the currency comes under immense speculative pressure.

that are symmetric only. The Revelation principle[7] applies and, subject to the feasible direct mechanism offered by the planner, foreign depositors play a non-cooperative withdrawal game, in which they report their type to the planner.

We construct a feasible mechanism that satisfies two main properties: (*uniqueness)* the direct mechanism implements an allocation that is consistent with a unique outcome of the withdrawal game of depositors (to be explained later) and (*optimal incentive compatible allocation)* the direct mechanism implements an allocation that is consistent with foreign depositors reporting their true types. We conjecture that any feasible (direct) mechanism that satisfies these two conditions, will implement the first-best allocation of the game.

With a soft peg, as per definition 7.1, the exchange rate between pesos and dollars is 1 : 1. The Central Bank's ability to reshuffle resources means that it can carry out investments in pesos whilst fulfilling its promises to meet contractual obligations in dollars. The optimisation problem for the Central Bank, as planner, follows the solution of the following optimal design problem:

$$\underset{c_1}{max}\ \lambda U\left(c_1\right)+\left(1-\lambda\right)U\left(c_2\right)$$

s.t

$$\lambda c_1 \leq \kappa$$

$$c_2=\frac{\left(1-\kappa\right)E\left(R\right)+\kappa-\lambda c_1}{1-\lambda}$$

$$c_1 \leq c_2$$

[7] The Revelation principle implies that the equilibrium allocation of the game that depositors play can be replicated as a truthful equilibrium of a game in which depositors are asked to report their types directly. Because of no aggregate uncertainty about liquidity shocks, the Law of Large Numbers (LLN) substitutes directly for the existence of such a direct mechanism.

Claim 7.1: *Given a continuous objective function and the existence of resource and incentive constraints that are compact and non-empty, there exists a solution to the optimal program. The assumptions of concavity and twice differentiability of the objective function, ensure that the solution is positive.*

The optimal program satisfies the following Euler equation: $U'(c_1) = E(R)\, U'(c_2)$ *and a resulting non-contingent term structure of demand deposit repayment, represented as follows*[8]*:*

$c_1 = \frac{\kappa}{\lambda}$, $c_2 = \frac{(1-\kappa)E(R)}{(1-\lambda)}$, $c_1 < c_2$.

Thus, $e = 1$ *in the foreign exchange market.*

Proof. See Technical Appendix (Section A.5) ■

The first expression following the main objective function, denotes the aggregate resource constraint that the Central Bank faces as a planner. The last expression is the incentive-compatibility (or truthtelling constraint). As proved in the technical appendix, optimising with respect to the budget constraints only, will automatically ensure that the incentive compatibility constraint is implicitly satisfied. The planner here is assumed to know the proportions of early and late withdrawals so that it devotes just the minimum required resources needed to satisfy consumer needs[9]. Thus, it provides a risk-sharing mechanism that allocates resources according to the true liquidity needs of agents and provides a smoothing device for R, by making it non state-contingent. As such, the planner provides insurance against both liquidity and aggregate risks and agents have an incentive to report their types truthfully. The economic intuition is that since it can observe and influence resource movements across time and states, it is the average return that accrues in all contingencies. The exchange rate stays at the same level as it was at the beginning of the experiment. The truthtelling behaviour of agents means that the aggregate demand for foreign currency is as planned and the exchange rate stays fixed.

[8] As mentioned before, c_1 and c_2 are stated in nominal (dollar) terms.

[9] Devoting fewer resources to the storage technology would increase the likelihood of a bank run whilst devoting more resources would result in an opportunity cost since the storage technology is unprofitable to hold.

7.2.2 Second-Best Allocation (Central Bank as Social Planner)

Now, assume that the Central Bank is still the supra-national authority that re-allocates resources within the banking industry but that it cannot observe the realisation of R. As in the first-best case, we assume that the planner will restrict attention to symmetric feasible (direct) mechanisms. Any feasible mechanism will now satisfy two properties: *uniqueness* (same as in first-best case) and *approximate optimality* - because the planner cannot observe R, it chooses a mechanism that attains a value for the expected utility of the depositor that is arbitrarily close to that attained under optimal incentive compatibility.

The optimisation problem will be as follows:

$$\max_{c_1} E[\lambda U(c_1(R)) + (1-\lambda) U(c_2(R))]$$

s.t

$$\lambda c_1(R) \leq \kappa$$

$$c_2(R) = \frac{(1-\kappa) R + \kappa - \lambda c_1(R)}{1-\lambda}$$

$$\int_0^{\frac{\kappa(1-\lambda)}{\gamma\lambda(1-\kappa)}} c_1(R)\ f(R)\ dR \leq \int_0^{\frac{\kappa(1-\lambda)}{\gamma\lambda(1-\kappa)}} c_2(R)\ f(R)\ dR$$

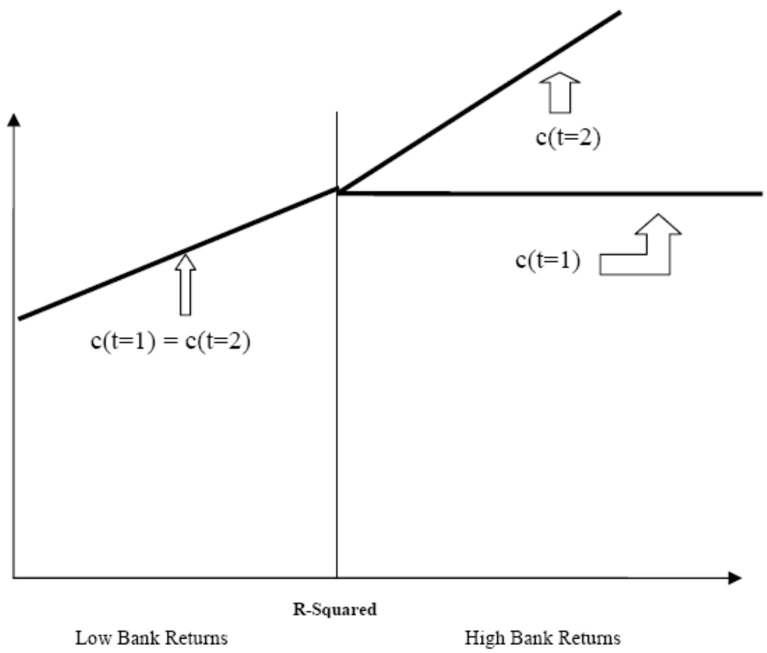
Claim 7.2: *The optimal solution results in a state-contingent term structure of demand deposit repayment of the following form:*

$c_1(R) = c_2(R) = (1-\kappa) R + \kappa \qquad R \leq R^{*}$[10]

$c_1(R) = \frac{\kappa}{\lambda}, \quad c_2(R) = \frac{(1-\kappa)R}{1-\lambda} \qquad R > R^{*}$

[10] The threshold is computed as follows: Let $\frac{\kappa}{\lambda} = \frac{(1-\kappa)R}{1-\lambda}$ at the point of indifference between consuming early and late. This boils down to: $R^{*} = \frac{\kappa(1-\lambda)}{\lambda(1-\kappa)}$. We know that $c_1(R) = \frac{\kappa}{\lambda}$. Thus, $R^{*} = \frac{c_1(1-\lambda)}{1-\kappa}$. This gives $\frac{c_1-\kappa}{1-\kappa}$ with $\lambda c_1 = \kappa$. Thus, $R^{*} = \frac{c_1-\kappa}{1-\kappa}$. Note that here, when $R \leq R^{*}$, the risky asset does not need to be liquidated. Since the Central Bank can reshuffle resources costlessly, it can bring some of its short-asset forward to supplement the low returns in period $t = 2$ whenever $R \leq R^{*}$.

FIGURE 7.2: Optimal Consumption Profile Under Second-Best Program



with $R^* = \left(\frac{c_1 - \kappa}{1-\kappa}\right)$

In the foreign exchange market, $e = 1$.

Proof. See Technical Appendix - similar to proof of claim 7.1 ■

7.2.3 Banking Contract Allocation

From Figure 7.2, if the risky returns are too low, the Central Bank can re-allocate resources across time so that part of the safe asset is carried forward into the future to complement the low earnings of patient consumers. The planner can provide insurance against liquidity shocks but not against aggregate shocks related to uncertain asset returns. Thus, there is no smoothing device for R in that it becomes state-contingent. Now, assume that the system is decentralized and that the Central Bank no longer acts as the social planner. The game is now defined as in the previous section, with (foreign) depositors depositing their money in their banks and the commercial banks choose an optimal portfolio to invest these endowments, whilst offering demand deposit contracts that are denominated in dollars. The typical bank's optimal design problem will be as follows:

$$\max_{c_1} \int_0^{\frac{\kappa(1-\lambda)}{\gamma\lambda(1-\kappa)}} \left[\lambda U\left(c_1\left(R\right)\right) + \left(1-\lambda\right) U\left(c_2\left(R\right)\right)\right] f\left(R\right)\ dR$$

s.t

$$\lambda c_1\left(R\right) \leq \kappa$$

$$c_2\left(R\right) = \frac{\left(1-\kappa\right) R + \kappa - \lambda c_1\left(R\right)}{1-\lambda}$$

$$\int_0^{\frac{\kappa(1-\lambda)}{\gamma\lambda(1-\kappa)}} c_1\left(R\right)\ f\left(R\right)\ dR \leq \int_0^{\frac{\kappa(1-\lambda)}{\gamma\lambda(1-\kappa)}} c_2\left(R\right)\ f\left(R\right)\ dR$$

To get a better picture of the vulnerabilities inherent in the bank's contractual obligations, we assume that, following the timeline of events as described in the previous section, the strategy of each depositor in period $t = 1$, is defined as a map from his 'type' space (including liquidity preference and interim information about the bank's performance) to his 'action' space (to stay or to withdraw). Depositors play a non-cooperative withdrawal game.

7.2.4 Anatomy of Financial Fragility

Given the above notion of strategy for depositors, we move on to describe the withdrawal rule:

Remark 7.1: *(***Withdrawal Decision Rule***) Given that in period $t = 1$, depositors receive a perfect interim signal of their bank's risky asset performance, they all choose to withdraw if $R \leq R^*$ (dominant to withdraw) and choose to stay if $R > R^*$ (dominant for all depositors to stay). $R^* = \left(\frac{c_1 - \kappa}{1 - \kappa}\right)$.*

The above remark highlights the fact that bank runs are purely information-related. Thus, our concept of bank runs follows the stream of Jacklin and Bhattacharya (1988), Allen and Gale (1998), Gorton (1988), Calomiris and Gorton (1991), rather than the sunspot-driven theories of Diamond and Dybvig (1983) and Chang and Velasco (2000a). This modelling has implications for the distribution of impatient and patient depositors that the bank faces. In the case when $R > R^*$, this distribution coincides with the liquidity preference shock distribution highlighted above (truthtelling behaviour induced). In the case of information-induced bank runs ($R \leq R^*$), there is violation of the truthtelling constraint and it is in the interest of all depositors to announce that they are impatient.

Remark 7.2: (**Competitive Banking Structure***) Banks operate in a perfectly competitive environment. Thus, given the term structure of demand deposit repayments* (c_1, c_2), *they choose an optimal portfolio allocation in period* $t = 0$, $(\kappa^*, 1 - \kappa^*)$ *for the safe and risky assets respectively. Given this optimal portfolio, they choose a consumption allocation for depositors* (c_1^*, c_2^*) *that maximises the utility of consumers subject to the constraint that their expected profits are zero*[11]*.*

Since κ^* and $1 - \kappa^*$ have been earmarked ex-ante, a bank run situation in

[11] As part of the banking contractual characterisation, we rule out "*run-proof*" contracts of the narrow banking type (i.e contracts that perfectly match the maturity structure of assets and liabilities e.g contracts that stipulate that the bank should hold storage assets at a level that could cover short-term payments to all depositors, should they all decide to withdraw prematurely). Such contracts are known to avoid bank runs at the cost of denting liquidity insurance provision.

which $R \leq R^*$ means that the bank does not have enough to meet the demand for all those who wish to withdraw. Crucially, it is forced to liquidate its risky asset (at a loss) in order to pay those who are withdrawing[12]. Given the sequential service rule, only a fraction of depositors will get back their due in a bank run environment[13]. Thus, the banking contract is made up of two parts: a "*crisis-prone*" element in which an information-induced bank run occurs - truthtelling is violated and all depositors queue up at the bank to demand repayment; a "*crisis-proof*" element in which truthtelling is achieved and thus, the distribution of early and late withdrawals coincides with the liquidity preference shocks (no bank runs).

The banking contract allocation can thus be viewed as the sum of two main elements:

$$\max_{c_1,\,\lambda} \int_0^{R^*} \Xi\, U\left(c_1\left(R\right)\right)\ f\left(R\right)\ dR + \int_{R^*}^{\frac{\kappa(1-\lambda)}{\gamma\lambda(1-\kappa)}} \left[\lambda U\left(c_1\left(R\right)\right) + \left(1-\lambda\right) U\left(c_2\left(R\right)\right)\right]\ f\left(R\right)\ dR$$

s.t

$$\lambda c_1\left(R\right) \leq \kappa$$

$$c_2\left(R\right) = \frac{\left(1-\kappa\right) R}{1-\lambda}$$

where $R^* = \frac{c_1 - \kappa}{1-\kappa}$, $\int_0^{R^*} \Xi\ U\left(c_1\left(R\right)\right)\ f\left(R\right)\ dR$ is the *crisis-prone element* of the contract (Ξ[14] denotes the proportion of those who receive full repayment under the sequential service constraint) and $\int_{R^*}^{\frac{\kappa(1-\lambda)}{\gamma\lambda(1-\kappa)}} \left[\lambda U\left(c_1\left(R\right)\right) + \right.$

[12] In the first and second best contract characterised earlier, costly liquidation was avoided.

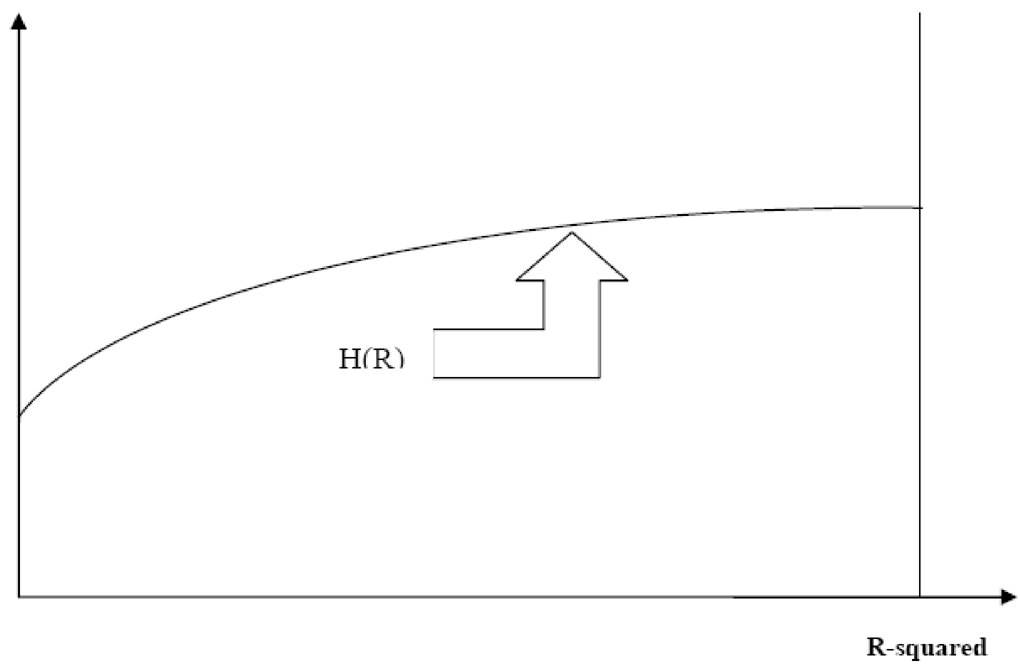
[13] The bank will carry on servicing those who withdraw early their due repayments until it has run out of resources completely.

[14] $\Xi = \frac{\kappa + \gamma(1-\kappa)R}{c_1^*}$. In a bank run situation, the amount available for payment is $\kappa + \gamma\left(1-\kappa\right) R$ where $\gamma\left(1-\kappa\right) R$ is the liquidated part of the risky asset. Under contractual obligations, the bank has promised to pay c_1^* to those who withdraw in period $t = 1$. Thus, whatever the bank has from its short asset and from its liquidated risky asset will be divided by c_1^* to determine the proportion of depositors who queue up and who receive full payments.

$(1-\lambda)\,U\,(c_2\,(R))]\ f\,(R)\ dR$ is the *crisis-proof element* of the contract (and truthtelling behaviour is induced). The banking contract allocation is weakly Pareto-dominated by the second-best allocation of the Central Bank as a planner. Whilst the banking contract can replicate the second-best allocation when there is no bank run, it clearly destroys risk-sharing mechanism when there are bank runs. Thus, in the no-run phase, the banking contract provides insurance against liquidity shocks but not against aggregate uncertainty about risky asset returns. The allocation is the same as that of the planner under the second-best plan. In the bank run phase, the bank just contends on providing full contractual repayment to a proportion Ξ of those who have queued up).

Note that while $\frac{\kappa+\gamma(1-\kappa)R}{c_1^*}$ represents an aggregate proportion, it does not discriminate between the types of those withdrawing. Thus, if $1-\lambda<\frac{\kappa+\gamma(1-\kappa)R}{c_1^*}$, and if all those who are first in the line of queue are patient depositors, it turns out that all patient depositors will receive payments and only some impatient depositors will receive their due - other impatient depositors will receive nothing. This "crisis-prone" element of the contract leads to inefficiency. More about this later.

FIGURE 7.3: Proportion of Foreign Depositors who receive Full Contractual Payment Under Sequential Service Constraint



7.3 Dynamics of Financial Crisis

We first start with a couple of definitions:

Definition 7.2: *(**Banking Crisis**)*[15] *A situation in which the bank is forced to liquidate its long asset to meet the demand for early withdrawals by depositors. Unless bailout facilities are organised, the bank ceases to be a going concern.*

Definition 7.3: *(**Currency Crisis**) A currency crisis is defined as a situation in which the international reserve level of the Central Bank falls to zero, so that the Central Bank is forced to devalue*[16]*.*

The theoretical literature focuses on two main channels of transmission from

[15] To construct a definition of banking crisis in the case of an EME is a tricky exercise, given the limited information availability on assets and liabilities. The notion of a banking crisis ultimately boils down to one of causality: does failure originate on the asset side (following, say, from deterioration of bank's asset quality) or from the liabilities side (following, say, from a run by depositors to withdraw) ? In the latter case, bank runs are the cause of the banking panic. Large withdrawals of deposits were observed in EME financial crises episodes of the 1980s and 1990s in Argentina, Phillipines, Thailand, Turkey and Venezuela. In the former case, the origins of banking crisis problem stem from the asset side (i.e induced, say, by the effects of a currency devaluation on assets). Crises of industrial nations in early 1990s (e.g Norway, Sweden and Finland) shared this feature. The issue of causality is important because it affects the construction of key indicators of banking crises. Definition 7.2 is exhaustive in that it remains impervious to such causality issues in banking crises.

[16] In the empirical literature, a currency crisis is defined as a situation in which the *real* exchange rate depreciates below a certain threshold level. How to compute the threshold level is a matter of debate among economists. Since we have assumed absolute purchasing power parity, we rule out this definition. The theoretical literature argues that to assume that a currency attack will take place when reserves fall to zero, would be to take a naive view of currency crises. If speculators are rational, they will mount an attack well before reserves have reached zero level, in order to take full advantage of arbitrage opportunities. See Krugman (1979) for more.

a banking crisis to a currency crisis. In its quest to supply dollars to depositors who withdraw, the Central Bank exchanges any home-currency proceedings from the short and long asset for foreign currency in order to satisfy contractual obligations in foreign currencies - the Central Bank loses reserves in the process, which makes it more likely that a currency crisis will prevail. Alternatively, resolving a banking crisis by the use of explicit governmental bailouts (e.g Lender-of-Last-Resort (LOLR)) may require the use of Central Bank reserves if the Central Bank is credit-constrained. The Central Bank typically sells reserves in the international market in exchange for pesos - which it uses to supply the domestic banking system in liquidity[17]. A Central Bank that uses reserves for the twinned task of defending a peg and of bailing out illiquid banks, runs the risk of generating a currency crisis by depleting the stock of reserves.

Banking crises have preceded currency crises in EMEs such as Turkey and Venezuela in mid-1990s. In this section, we unearth the exact nature of the transmission mechanism that spreads a crisis from the banking system to the foreign exchange market. We start with the case in which no lending policy is designed by the Central Bank and we proceed on to analyse the nature of the transmission process when such interventionist policy is possible. In both cases, we provide necessary and sufficient parametric restrictions that will guarantee the existence of any potential linkages.

7.3.1 No Interventionist Policy

With no interventionist policy administered by the Central Bank in the form of LOLR, we show that, with an exchange rate of $1:1$, the central bank has enough reserves in its coffers in the form of dollars to meet the needs of depositors who withdraw - no currency crisis (as per definition 7.3) is generated as a result.

[17]In practice, the Central Bank refrains from printing pesos for this task because so-doing will create inflation and may affect the macroeconomic credentials of the country.

When $R \leq R^*$, the amount available for distribution to depositors will consist of κ (i.e the short asset) and $\gamma(1-\kappa)R$ (i.e the value of the liquidated long asset). Thus, in the negotiation phase in period $t = 1$, the total amount of pesos that the commercial bank will want to convert into dollars is: $\kappa + \gamma(1-\kappa)R$. Under the contractual arrangement, the bank promises to pay c_1^* to those who present themselves to the bank. Thus, proportion $\frac{\kappa+\gamma(1-\kappa)R}{c_1^*}$ (i.e Ξ) receive c_1^*. Since the bank has liquidated its long technology, it is no longer a going concern in period $t = 2$ (as per definition 7.2). The remaining proportion of depositors (i.e $1-\Xi$) receive nothing. The Central Bank, in period $t = 1$, has 1 dollar in its reserves. Given that $\gamma R < 1$, it follows that: $1 > \kappa+\gamma(1-\kappa)R$. Thus, the total dollar supply in the Central Bank's reserves more than offsets the commercial bank's demand for exchanging pesos for dollars.

Proof. We know that $1 > \gamma R$

Multiply both sides by $(1-\kappa)$ yields : $1-\kappa > \gamma(1-\kappa)R$

Thus, $1 > \kappa + \gamma(1-\kappa)R$

Q.E.D ■

We subsume two further lemmas that will be useful for future proofs, depending on parametric restrictions that we have imposed earlier:

Lemma 7.1: *Given parametric restrictions* $\lambda < \frac{2\kappa}{\kappa+1}$ *and* $\gamma R < 1$*, it follows that* $\frac{1}{2} < R^* < 1$

Proof. See Technical Appendix (Section A.5) ■

Lemma 7.2: *Given that* $\frac{\kappa}{1-\kappa} \geq \frac{\lambda}{1-\lambda}(\gamma R)$, *it follows that:* $0 < \gamma R < R^*$

Proof. See Technical Appendix (Section A.5) ■

We conjectured the existence of assumption $\frac{\kappa}{1-\kappa} \geq \frac{\lambda}{1-\lambda}(\gamma R)$ earlier. We now show that these assumptions are natural and are consistent with the equilibrium play of game of this model. First, a general proposition:

FIGURE 7.4: Payment Structure for Depositors

	Payoff if Depositor Stays	Payoff if Depositor Withdraws
$\mathbf{R \geq R^*}$	$\frac{(1-\kappa)R}{(1-\lambda)}$ (i.e c_2*)	$\frac{\kappa}{\lambda}$ (i.e c_1*)
$\mathbf{R < R^*}$	0	$\frac{\kappa}{\lambda}$ if depositor is among Ξ 0 if depositor is not among Ξ

Proposition 7.1: *Bank runs occur if and only if $R \leq R^*$ but in the absence of any interventionist policies, will fail to spread contagiously to the foreign exchange sector and to generate a currency crisis as per definition 7.3. A necessary and sufficient condition that guarantees this result is assumption* $\frac{\kappa}{1-\kappa} \geq \frac{\lambda}{1-\lambda} (\gamma R)$

Proof. See Technical Appendix (Section A.5) ■

7.3.2 Welfare Implications of Information-Induced Bank Runs

Figure 7.4 (illustrated above) summarises the net payoff structure of depositors as a function of bank fundamentals and as a function of the timing of their withdrawal decisions.

If $R \geq R^*$, it is strictly dominant for all patient depositors to stay. The sequential decision rule and the perfect signal act as coordination devices. The only depositors who withdraw are those who have genuine liquidity needs. Thus, the probability distribution of impatient and patient depositors is consistent with the aggregate liquidity distribution of depositors. In multiple equilibria models of Chang and Velasco (2000a) and Diamond and Dybvig (1983), each depositor is better off withdrawing conditional on others withdrawing even though, as a whole, they would be better off if they refrained from so doing. Conversely, if $R < R^*$, it is weakly dominant to withdraw - depositors get 0 if they choose to stay since all assets are liquidated. If they choose to withdraw early, their payoffs will depend on whether they are among Ξ in the queue.

Bank runs clearly lead to inefficient allocation compared to first and second best allocations of the Central Bank as a planner. Given the existence of a sequential decision rule, it is possible to have several subcategories (depending on the order in which depositors present themselves to the bank) such that several inefficiencies arise and can be Pareto-ranked. There are three possibilities[18]:

Case 1: All impatient depositors are first in the queue (they are all within the Ξ group). In this case, all impatient depositors receive c_1^*. Of the patient depositors, a proportion $\frac{\gamma(1-\kappa)R}{c_1^*}$ receives c_1^* while the rest receive nothing.

Case 2: All patient depositors present themselves first in the queue. There are two sub-possibilities here: while it is true that $\frac{\kappa+\gamma(1-\kappa)R}{c_1^*} > \lambda$, it is indeterminate as to whether $\frac{\kappa+\gamma(1-\kappa)R}{c_1^*}$ is larger or smaller than $1-\lambda$;

[*a*] In the case in which $\frac{\kappa+\gamma(1-\kappa)R}{c_1^*} > 1-\lambda$, all patient depositors receive c_1^*. Some impatient depositors (fraction of $\frac{\kappa+\gamma(1-\kappa)R}{c_1^*} - (1-\lambda)$) receive their promised c_1^* while the remaining proportion of impatient depositors get 0;

[*b*] In the case in which $\frac{\kappa+\gamma(1-\kappa)R}{c_1^*} \leq (1-\lambda)$, the first proportion $\frac{\kappa+\gamma(1-\kappa)R}{c_1^*}$ of patient depositors receive c_1^*. The remaining proportion of patient depositors (fraction $(1-\lambda) - \frac{\kappa+\gamma(1-\kappa)R}{c_1^*}$) receives nothing. All impatient depositors receive nothing.

Case 3: Queue contains a mix of impatient and patient depositors and the first Ξ of the line contains a mix of impatient and patient depositors) - Intermediate case between cases 1 and 2.

Claim 7.3: *While bank runs result in inefficiency, there are three subcategories of runs that can be Pareto-ranked, depending on the sequence of order*

[18] Bear in mind that $\Xi > \lambda$.

in which depositors present themselves to the queue. Case 2(b) is strictly Pareto inferior to case 2(a), which, in turn, is Pareto inferior to case 1. In addition to entailing liquidation of assets, case 2(b) results in complete denial of liquidity to impatient depositors.

7.3.3 Interventionist Policy - How effective is LOLR[19] in an EME?

The literature on LOLR was reviewed in section 2.4.2 of **chapter 2**. For an EME characterised by liability dollarisation, a fixed exchange rate regime means that the liabilities of the banking system are implicit obligations in the international currency. Using international reserves to defend the peg and to bailout troubled banks, may lead to a drying up of international liquidity of the economy and may provide a perfect recipe for a currency crisis (as per definition 7.3).

Lets assume that, instead of liquidating the long asset (yielding $\gamma\left(1-\kappa\right)R$), the Central Bank lends this amount to the commercial bank by depleting its reserves of dollars from its coffers. Given a fixed exchange rate of 1 : 1, the amount of dollars that the Central Bank depletes is $\gamma\left(1-\kappa\right)R$. It sells this amount of dollars in the international market in return for pesos. To analyse the role of the Central Bank's LOLR function, we modify the timeline of events described earlier, as follows:

[19] In practice, Central Banks intervene using LOLR if the problem plaguing the banking system is one of illiquidity (not of insolvency) and if it fears that the failure of the illiquid bank will have a negative contagious impact on the whole banking system and financial markets.

[1] Financial System is liberalised

Period t = 0

[2] Foreign investors deposit their endowment of 1 dollar in the bank, in return for a demand deposit contract that promises to pay them in dollars

[3] The commercial bank decides on the optimal portfolio allocation

[4] The commercial bank exchanges dollars for pesos at the Central Bank at a fixed exchange rate of 1:1

[5] The bank invests resulting pesos in the safe technology and in long technology

Period t = 1

[6] Depositors learn their types and receive a perfect signal of their bank's performance that will prevail in period t=2

[7] Depositors queue up at the bank in order to demand repayment of their deposits

[8] Central Bank lends to commercial bank an amount which is equal to the proceeds from the liquidated asset, under its LOLR scheme

[9] The commercial bank negotiates with the Central Bank for the exchange of pesos for dollars in the foreign exchange market at the prevailing exchange rate (**Ist Round**)

[10] Those depositors who demand repayment will be paid in dollars on a First-Come-First-Served (FCFS) basis

Period t = 2

[11] The commercial bank pays its borrowed LOLR amount to the Central Bank (discount rate is zero) out of its long asset proceeds

[12] Depositors who have chosen to stay in the bank, demand repayment in dollars

[13] Banks negotiate with the central bank for the exchange of pesos for dollars out of remaining asset proceeds in the foreign exchange market at the prevailing exchange rate (**2nd Round**)

[14] These depositors are paid on a pro-rata basis

Thus, when $R \leq R^*$ under LOLR arrangement, the amount available for distribution to depositors will consists of κ (derived from the safe asset) and $\gamma(1-\kappa)R$ (derived from borrowings from the Central Bank.) Under the contractual arrangement, the bank promises to pay c_1^* to those who present themselves to the bank. Thus, a proportion $\frac{\kappa+\gamma(1-\kappa)R}{c_1^*}$ (i.e Ξ) receives c_1^*. Since the bank is still a going concern (long assets are not liquidated), its returns in period $t=2$, will be $(1-\kappa)R - \gamma(1-\kappa)R$ (or $(1-\kappa)(1-\gamma)R$), where $(1-\kappa)R$ is the return to the long asset and $\gamma(1-\kappa)R$ is the payment[20] to the Central Bank for having borrowed under the LOLR window in period $t=1$. The amount will be available to those (i.e proportion $1-\Xi$) who did not receive payment in period $t=1$. Thus, each depositor who was 'forced' to stay until period $t=2$, receives: $\frac{(1-\kappa)(1-\gamma)R}{1-\Xi}$.

The Central Bank, in period $t=1$, has $[1-\gamma(1-\kappa)R]$ dollars in its reserves, where $\gamma(1-\kappa)R$ represents the amount it has lent to commercial bank under the LOLR scheme. We know that $0 < \gamma R < R^*$. By construction, if $0 \leq \gamma R \leq \frac{1}{2}$(bearing in mind that $\frac{1}{2} < R^*$), the amount of dollars available exceeds the amount of pesos supplied by commercial banks to the Central Bank i.e $1-\gamma(1-\kappa)R > \kappa+\gamma(1-\kappa)R$. If this is true, in period $t=2$, the Central Bank has $1-2\gamma(1-\kappa)R-\kappa+\gamma(1-\kappa)R$ dollars (i.e $(1-\kappa)(1-\gamma)R$ dollars.) The proportion of depositors withdrawing is $1-\Xi$ and each depositor earns $\frac{(1-\kappa)(1-\gamma)R}{1-\Xi}$amount of pesos supplied by those withdrawing in period $t=2$. Total amount supplied is: $(1-\kappa)(1-\gamma)R$ pesos. Given the $1:1$ exchange rate between pesos and dollars, the Central Bank reserves exactly cover the pesos it receives. Thus, the Central Bank does not run out of reserves at any point of time in the game. This finding can be captured in the following corollary:

Corollary 7.1: *If $0 < \gamma R < \frac{1}{2}$, under the sequential decision rule and given depositors' strategy , LOLR prevents an information-based bank run from*

[20] We assume that the discount rate is zero.

contagiously spreading to foreign exchange sector and from generating a currency crisis as per definition 7.3.

For the range of values of γR, such that $\frac{1}{2} < \gamma R < R^{*}$, the amount of dollars available at the Central Bank in period $t = 1$ (i.e $1-\gamma(1-\kappa)R$) is less than the amount of pesos available at the commercial bank (i.e $\kappa + \gamma(1-\kappa)R$). The Central Bank runs out of reserves to finance those demanding payment. An international illiquidity problem arises at the macroeconomic level, which leads to a currency crisis, as per definition 7.3. Our result that LOLR may, under certain circumstances, be sub-optimal in EMEs, is an important contribution we make to the literature. Closed-economy considerations of LOLR measures show that, by preserving the value of assets of banks facing liquidity (but not solvency) problems, a bank run is always avoided. Our paradigm suggests that this may not necessarily be the case since LOLR may come at a cost to other banks if the LOLR measure drains the international liquidity of the economy. Thus, our paradigm advocates that alternative ways of financing the LOLR scheme need to be sought. Our hypothesis that LOLR may not always be welcomed as a crisis management measure, rejoins the idea of some closed-economy contributions such as Goodhart and Huang (2005). While adopting a completely different approach, Goodhart and Huang (2005) argue that, in a dynamic setting, the trade-off between contagious probabilities and moral hazard considerations, is crucial in determing the optimal policy in terms of liquidity support that the Central Bank provides to banks (LOLR). As a result of suboptimality, they rationalise the case for "constructive ambiguity" in the intervention of the Central Bank, rather than systematic interventions when banks need cash.

FIGURE 7.5: Parametric Restrictions for LOLR to result in Contagious Flow From a Banking Crisis to a Currency Crisis

ABSENCE OF INTERVENTIONIST POLICIES (LOLR) => Currency Crisis never occurs

=> **Assumption**: $\frac{\kappa}{1-\kappa} > \frac{\lambda}{1-\lambda}(\gamma R)$

IN THE PRESENCE OF LOLR => Assumptions:

$\frac{\kappa}{1-\kappa} > \frac{\lambda}{1-\lambda}(\gamma R)$

$\lambda < \frac{2\kappa}{\kappa+1}$

$\gamma R < 1$

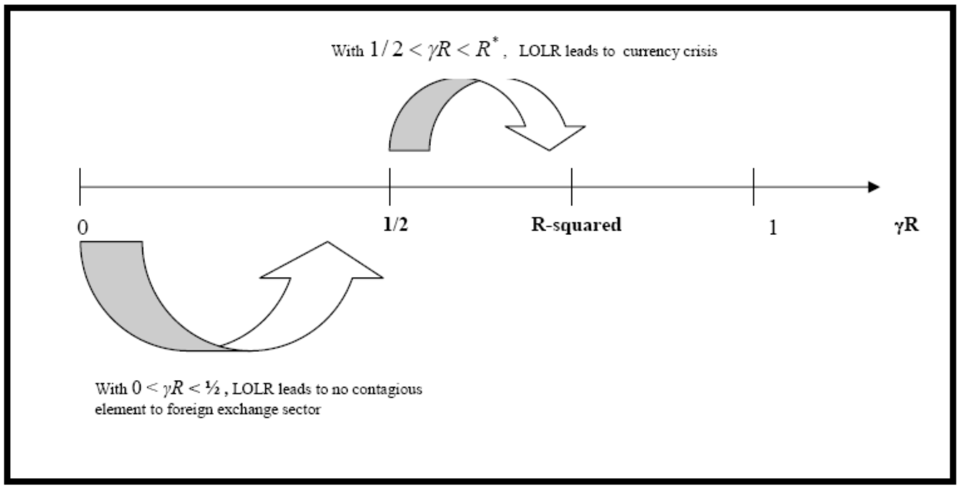
CASE A: LOLR leading to no currency crisis

=> Sufficient Condition: $\gamma R < \frac{1}{2} < R^*$ *(<1)*

CASE B: LOLR leading to currency crisis

=> Sufficient Condition: $\frac{1}{2} < \gamma R < R^*$ *(<1)*

FIGURE 7.6: Parametric Restrictions for LOLR to result in Contagious Flow From a Banking Crisis to a Currency Crisis



7.4 Some Applications

7.4.1 Special Conjecture for LOLR - A Multi-Period Hypothesis with Many Banks

In this section, we extend the reasoning behind our model predictions to a multi-period setting of a financial system with many banks and explore some implications of our paradigm.

Assume that : $\frac{1}{2} < \gamma R \leq R^*$. What are the implications of LOLR for an EME with liability dollarisation ? We conjecture the existence of some vicious circle of financial fragility as follows:

Corollary 7.2: (**"Illiquidity Externality" Syndrome**) *Any bailout scheme engineered ex-post by the Central Bank is inefficient because of the externality it creates for the international liquidity of the economy in general*

The use of LOLR[21] to bailout troubled banks creates a spillover effect of its

[21] In practice, LOLR affects the monetary base of the financial system and, hence, will

own right on the country's international liquididty position and, as such, may impinge on the overall macroeconomic management goals (e.g defense of the peg). Furthermore, bad macroeconomic policies, per se, may lead to currency crises and will result in balance sheet effects - which aggravate the banking crisis to begin with and, thereby, affect the likelihood of using interventionist policies.

Corollary 7.3: (**Intertemporal Substitution of Banking Crisis**) *A LOLR scheme engineered by the Central Bank may avoid a contemporary information-based banking failure at the crisis-catalyst bank, at the cost of a larger devaluation-induced banking failures across all other banks in the future*

To analyse the welfare implications of LOLR scheme, a comparison must be made between the welfare gains from preventing contemporary bank failure and the welfare losses that result from spillover effects on international liquidity of the economy and the welfare losses that emanate from future banking failures as a result of a devaluation-induced banking crisis in the future[22].

Corollary 7.4: *LOLR is ex-post sub-optimal in an EME characterised by liability dollarisation*

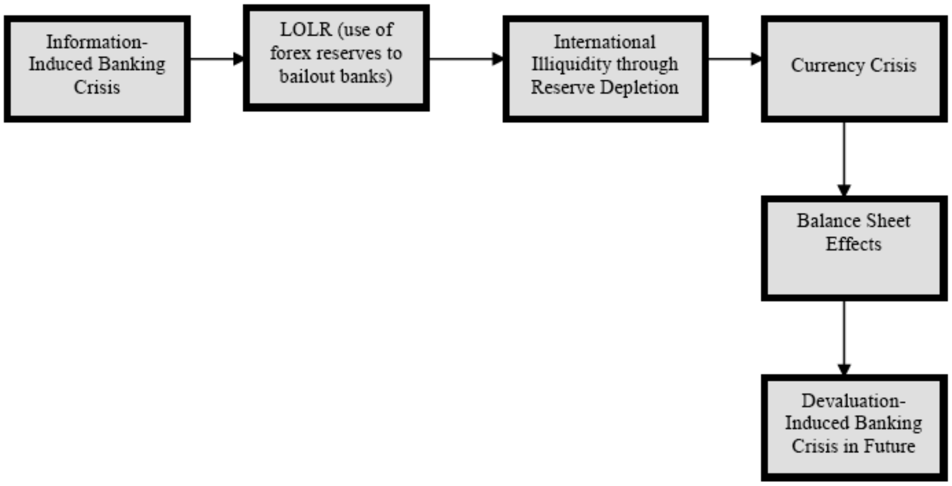
Proof. See Technical Appendix (Section A.5) [23] ■

impinge on the effectiveness of monetary policy. Monetary policy, in its own right, may affect the stability, safety and soundness of the banking system through the banking or the credit channel of the monetary transmission mechanism - thereby affecting the probability of intervening using microeconomic policies such as LOLR. The EME case is special because it shows that these two distinct functions of a central bank, are interconnected, as per the above illustration.

[22] See **chapter 8** for more on devaluation-induced banking failures.

[23] The fact that a devaluation-induced bank failure results in greater welfare loss than a purely information-based failure, has implications for the practical choice of macroeconomic policy instruments available to an EME when it comes to defending the soft peg. EMEs prefer to use **interest rate policy** to defend the peg rather than **foreign market intervention.** The former policy will weaken the banking system through the adverse selection and moral hazard arguments we outlined earlier. The latter will induce a currency devaluation (by

FIGURE 7.7: Intertemporal Substitution of Banking Crisis



The interconnections generated by LOLR, through illiquidity spillover effects and intertemporal substitution of banking crises (illustrated in Figure 7.7), suggests that the interplay between financial fragility and overall macroeconomic aims, is strong for a EME with liability dollarisation. The "cause-effect" chain, through which a LOLR scheme is shown to have a contagious impact on international liquidity of the economy and future banking fragility, suggests that the need to coordinate the financial stability role (ensuring safety and soundness of the banking system) and overall macroeconomic aims (ensuring monetary stability and exchange rate policy), is of fundamental importance for the Central Bank of an EME.

Corollary 7.5: *Assume that depositors receive interim news about the bank's portfolio peformance, devaluation (i.e currency crisis - as per definition 7.3) occurs if and only if* $R \leq R^*$ *and if, under assumption* $\frac{1}{2} < \gamma R < R^*$*, the Central Bank uses interventionist policies in the form of LOLR to bail out*

depleting reserves) and will result in balance sheet effects. Corollary 7.4 suggests that, in welfare terms, it is less costly to bear the burden of higher interest rates than to bear the burden of currency crisis induced by draining of reserves as a result of foreign market intervention.

FIGURE 7.8: Transmission Mechanism From Banking Crisis to Currency Crisis

CAUSE / EFFECT	**Bank Run occurs ($R < R^*$)**	**No Bank Run occurs ($R \geq R^*$)**
Devaluation	Interventionist Measures such as LOLR Assume: $\frac{\kappa}{1-\kappa} > \frac{\lambda}{1-\lambda}(\gamma R)$ $\lambda < \frac{2\kappa}{\kappa+1}$ $\gamma R < 1$	Nil
No Devaluation	No LOLR	Nil

banks facing liquidity trouble.

7.4.2 Economics of Capital Controls and Application to EME with Liability Dollarisation

In the wake of the East Asian crisis of 1997 / 8, Malaysia adopted capital controls and the policy was successful in preventing the exodus of capital and in shielding the economy from external shocks. We interpret capital flows here as a quantitative restriction on the influx of foreign investors depositing their endowments in the domestic banking system of an EME. Fischer (2001)[24] argues that the rationale for imposing capital controls is twofold:

[1] *Controls on capital inflows* - prevent excessive capital inflows from leading to currency overvaluations or to influence the distribution of capital inflows towards long term capital and away from short run disruptive capital inflows.

[2] *Controls on capital outflows* - prevent devaluation of the currency precipitated by a herding behaviour of depositors in moments of panic and to give

[24] Fischer, Stanley (2001): "Exchange Rate Regimes: Is the Bipolar View correct ?", summarised in *Finance & Development,* IMF Quarterly Publication, and full edition available in *Journal of Economic Perspectives,* Vol. 15, No. 2, Spring 2001

allow country to have independent control over monetary policy[25] with a fixed exchange rate regime.

The theoretical literature argues that Suspension-of-Convertibility (SoC) (or the closed-economy equivalent of capital controls) successfully act as *bank-run preventing devices* but that whether the socially optimal outcome will result depends on the presence of aggregate uncertainty about liquidity shocks. In the absence of such uncertainty, banks offering demand deposit contracts with suspension help achieve socially optimal allocation and help ward off a bank run. In the presence of this uncertainty, SoC eliminates a bank run but results in sub-optimal allocation because it cannot allow for contingent allocation[26].

In this section, we assume that the exchange rate is a soft peg and that the government is committed to maintain it at this level due to the "fear of floating" argument that results from allowing the currency to float. Thus, foreign depositors receive information about the bank's performance only and not about the shadow exchange rate.

Recall the strategy of depositors as per remark 1: if $R > R^*$, is a dominant strategy for depositors to stay (thus the proportions of early and late consumers will coincide with the liquidity preference shock, $(\lambda, 1-\lambda)$). Conversely, if $R \leq R^*$, it is dominant for every depositor to withdraw. Let us assume that $R \leq R^*$ and that, as part of its crisis-management measure, the government adopts a quantitative restriction of capital that can flow out of the country. In particular, let us assume that, under this capital control on outflows, the bank promises to service only the first λ of depositors who present themselves to the bank. The

[25] This is the "impossible trilemma" doctrine in the literature that it is impossible to have complete monetary autonomy, fixed exchange rate and perfect capital mobility at the same time. To enable an economy to have independent control over its monetary policy in a system of fixed exchange rate, capital controls on outflows are necessary.

[26] This warrants the intervention of the government through the use of public measures, such as deposit insurance schemes, because deposit insurance allows for contingent allocation, and can replicate the socially-optimal allocation.

FIGURE 7.9: Term Structure of Payments to Depositors

CASE A: All Impatient Depositors Present Themselves First In Line of Queue

In Period t = 1	**Impatient Depositors**	**Patient Depositors**
Without Controls	All receive c_1^* (**Note1**)	Some receive c_1^* (**Note2**) Others receive nothing (**Note 3**)
With Controls	All receive c_1^* (**Note1**)	All receive 0 (**Note 4**)
Note: (recall: $\Xi > \lambda$) **1. Proportion λ** **2. Proportion $\Xi - \lambda$** **3. Proportion 1- Ξ (SSC)** **4. Proportion 1- λ**		
In Period t = 2	**Impatient Depositors**	**Patient Depositors**
Without Controls	All have been paid in period t=1	Remaining receive nothing (**Note 5**)
With Controls	All have been paid in period t=1	All receive c_2^*
Note: (recall: $\Xi > \lambda$) **5. Proportion 1- Ξ (Due to Liquidation)**		

main aim of imposing such capital controls is to prevent a bank run and help restore the Planner's Second-Best solution.

FIGURE 7.10: Term Structure of Payments to Depositors

CASE B: All Impatient Depositors Present Themselves First In Line of Queue

In Period t = 1	**Impatient Depositors**	**Patient Depositors**
	Assumption: $\Xi > 1-\lambda$	
	Some receive c_1* (**Note 6**) Others receive 0 (**Note 7**)	All receive c_1*
Without Capital Controls	Assumption: $\Xi < 1-\lambda$	
	All receive 0	Some receive c_1* (**Note 8**) Others receive 0 (**Note 9**)
	Assumption: $\lambda > 1-\lambda$	
With Capital Controls	Some receive c_1* (**Note 10**) Others receive 0 (**Note 11**)	All receive c_1*
	Assumption: $\lambda < 1-\lambda$	
	All receive 0	Some receive c_1* (**Note 12**) Others receive 0 (**Note 13**)

Note:

6. **Proportion Ξ-1+κ**
7. **Proportion 2-Ξ – κ**
8. **Proportion Ξ**
9. **Proportion 1- λ- Ξ**
10. **Proportion 1- 2λ**
11. **Proportion 3λ-1**
12. **Proportion λ**
13. **Proportion 1- 2λ**

In Period t = 2	**Impatient Depositors**	**Patient Depositors**
	Assumption: $\Xi > 1-\lambda$	
Without Controls	Remaining receive 0 (**Note 14**)	All paid in t=1
	Assumption: $\Xi < 1-\lambda$	
	All receive 0	Remaining receive 0 (**Note 15**)
	Assumption: $\lambda > 1-\lambda$	
With Controls	Some receive c_2* (**Note 16**)	All paid in t=1
	Assumption: $\lambda < 1-\lambda$	
	All receive c_2*	Remaining receive c_2* (**Note 17**)

Note:

14. **Proportion 2-Ξ – κ**
15. **Proportion 1-Ξ – λ**
16. **Proportion 3λ-1**
17. **Proportion 1- 2κ**

Capital Controls[27] can successfully act as *bank-run preventing devices* but whether they can replicate the planner's optimal allocation depends on the order in which depositors present themselves to the bank. If all those who are first in the queue are impatient depositors, capital controls prevent runs and achieve an allocation in which impatient depositors receive c_1^* and patient depositors receive c_2^* in period $t = 2$ (banking contractual obligations satisfied). If the sequence order is different (i.e patient depositors get paid first due to them being first in the line of queue), controls on outflows achieve a sub-optimal allocation e.g when $\lambda < 1 - \lambda$, all impatient depositors are forced to consume in period $t = 2$ when consumption is of no avail to them.

An operational problem that arises with capital controls in our setup, is that if the controls on outflows are extensive, this may act as a deterrent to foreign investors or depositors to deposit their money in the domestic banking system to begin with. Given that we assumed that there are no domestic investors, this may thwart financial intermediation. Furthermore, for economies that have an open capital market and that are signatories to free trade in goods and services agreements (under the World Trade Organisation (WTO) accords), it is difficult to imagine closing the capital account of the Balance of Payments, whilst still maintaining the current account open and fully convertible.

Corollary 7.6: *Capital Controls act as potential and successful bank-run preventing devices but:*

[27] As mentioned before, the practical reasons for limiting outflows of capital are essentially macroeconomic in nature: to prevent outflows from devaluing the currency and to allow monetary policy independence to co-exist with a fixed exchange rate regime. Monetary policy, in the macroeconomic sense, is not the issue of the paper - thus, can be dropped down. Our theoretical analysis of crisis flow from the banking sector to the external sector, shows that a necessary and sufficient condition to generate a currency crisis, is the presence of interventionist policies such as LOLR. Without interventionist policies, there are always sufficient reserves in the Central Bank coffers to finance the needs of those who wish to withdraw. Thus, we can, as well, dump down the benefits of capital controls as pre-emptors of currency devaluation in this paper.

[1] *They may result in mis-allocation of resources, depending on the sequence order at which depositors present themselves to the bank.*

[2] *In a dynamic setting with perfectly foresighted foreign depositors, capital controls on outflows lead to ex-post prevention of bank failures and ex-ante dis-incentive for depositors to deposit their money in the bank in the first instance. The optimal level of restriction will depend on the trade-off between ex-post bank run prevention and ex-ante financial dis-intermediation effects.*

We review some other implications of our paradigm for the economics of capital controls in the last section of the next chapter.

7.5 Conclusion

This chapter studies a banking allocation in an emerging market economy characterised by foreign influx of capital and by liability dollarisation. The main contributions embodied in this chapter are manifold. We show that, using a mechanism design approach, there is a pecking order in implementation of optimal resource allocation. We show that a Planner who is assumed to observe all stochastic fundamentals of the banking system, will offer a direct truthtelling mechanism that implements the First-Best implementation of resources. The Planner provides full insurance against liquidity and aggregate risks in the economy and the resulting term structure of demand deposit payments to depositors is non-contingent. Under the assumption that the Planner is unable to observe the stochastic fundamentals, the allocation becomes Second-Best and the Planner can only insure against liquidity risks. The term structure of payments becomes contingent on the stochastic fundamentals of the banking system. A decentralised banking system is characterised by positive endogenous probabilities of banking failures. When these failures do not occur, banks implement the Planner's Second-Best allocation. When banking failures occur, the banking system results in an allocation that is Pareto inferior to that of the Planner. We show that within this inferior allocation, there are a number of sub-categories of banking allocation, depending on the order in which depositors present themselves to the bank.

Our next contribution is to analyse the nature of the transmission mechanism from a banking crisis to a currency crisis under the assumption that a banking failure has occured. In the banking allocation, we show that, when depositors receive precise information about their bank's stochastic fundamental, a unique equilibrium in the bank's fundamental, exists in depositors' strategy. Given that deposit contracts are denominated in dollars (and the fact that depositors consume in dollars), the Central Bank will never run out of reserves to finance contractual payments in dollars. The necessary and sufficient condition that guarantees this is: $\frac{\kappa}{1-\kappa} > \frac{\lambda}{1-\lambda}(\gamma R)$. When this condition is violated, we move on to analyse the nature of the specific conduit through which a banking crisis may contagiously spread to the foreign exchange sector. Through our innovative approach, one of our key results and contributions to the literature, is that we show that LOLR may sometimes be the key channel that contagiously transmits a crisis from banks to the foreign exchange sector. Thus, in an EME, we show that LOLR can be sub-optimal, even if it succeeds in preserving the assets of the crisis-catalyst bank. In particular, we show that if $\frac{1}{2} < \gamma R < 1$, any ex-post bailout strategy designed to prevent asset liquidation, will always lead to a drying up of international liquidity and to an eventual currency devaluation. Thus, we show that using the foreign reserves for the twinned task of defending the peg and of bailing out illiquid banks through LOLR, may be destabilising. An interesting conjectural application is that of a multi-period financial system with many banks. This setting leads to a completely new outcome to the literature in that we show that in an EME, ex-post bailout strategies such as LOLR may lead to an intertemporal substitution of banking crisis: whilst helping to ward off a contemporary information-based banking crisis, they may lead to future currency devaluations which induce balance sheet effects and to eventual devaluation-induced banking failures. With devaluation-induced banking failures resulting in larger welfare loss than information-induced banking failures, LOLR may thus be sub-optimal for the financial system of an EME.

Our third contribution to the literature is to provide the theoretical tools to conduct welfare analysis of various policy instruments for open-economy banking systems. This departs fundamentally from Chang and Velasco (2000a) whose contribution is to analyse nature of equilibrium (uniqueness or multiple equilibria) in open-economies. Chang and Velasco (2000a) argued that the main limitation of their work, is that it cannot be used to assess the effectiveness of various policies. Our contribution is meant to address that gap. The appealing feature of the mechanism design approach that we adopt, is that it enables us to measure, in welfare terms, the effectiveness of various policy measures designed to tackle a banking crisis problem. The success of any policy depends on its ability to restore the Planner's Second-Best outcome. We consider the effectiveness of a a number of policies (e.g capital controls, state-contingent controls, Chilean taxes) in this chapter.

In the next chapter, we will consider a related issue which builds on the environment considered in **chapter 6** but which documents the reverse transmission process from a currency crisis to a banking crisis.

Chapter 8

Devaluation-Induced Banking Failures

8.1 Introduction

This chapter builds on **chapter 6** and considers an alternative question to the one we considered in **chapter 7**. Our aim here is to highlight the nature of the transmission mechanism from a currency crisis to a banking crisis and to analyse the necessary and sufficient conditions for such a transmission process to occur. We also want to shed light on the debate on the most appropriate form of the exchange rate regime and the accompanying safeguards that may be adopted by an EME - where the appropriate form of the exchange rate regime is the one that minimises the probability of either form of crisis.

As we documented in **chapter 6**, the literature on the twin crisis is relatively more tilted on the empirical side, with notable contributions from Kaminsky and Reinhart (1999). The main theoretical work comes from Chang and Velasco (2000a). Chang and Velasco (2000a) extend the Diamond and Dybvig (1983) framework to an open economy and analyse multiplicity of equilibria, with one equilibrium depicting the occurrence of the 'twin crises' and the other equilibrium depicting otherwise. A natural outcome of their paradigm is to enunciate the circumstances under which the twin crises occur as equilibrium phenomenon.

We extend a banking system to an open economy by adopting an environment that is similar to Chang and Velasco (2000a). Our work differs from Chang and Velasco (2000a) in two main respects: Firstly, we focus on Allen and Gale (1998) banks rather than Diamond and Dybvig (1983) banks - which means that, with an incomplete information structure, we automatically preclude multiplicity of equilibria. Secondly, we focus on the nature of the transmission mechanism from a currency crisis to a banking crisis and explore the necessary and sufficient conditions under which a currency crisis will give rise to a banking crisis. Real world examples as documented by empirical studies carried out by Kaminsky and Reinhart (1999), show that a currency crisis may cause a banking crisis through the effects of a currency devaluation on the balance sheets of banks that are characterised by liability dollarisation. In addition, resolving a currency crisis may, by itself, lead to trouble in the banking sector if it requires massive interest rate hikes which fragilise banks by inducing adverse selection and moral hazard in their asset portfolio. Theoretical contributions that document the exact nature of the transmission process, are lacking in the literature and our work is meant to fill that gap.

Like in Chang and Velasco (2000a), there are two currencies: pesos (the home currency) and dollars (the foreign currency) and three time periods: $t = 0, 1, 2$. All consumers are foreign investors who are endowed with 1 dollar each. They deposit their endowment of 1 dollar at the bank. The bank is modelled as a mechanism that accepts deposits of dollars from foreign investors and proceeds to convert these dollars into pesos at the Central Bank and to invest some of these pesos in a safe storage asset (that yields a return of 1 unit in period $t+1$ for each unit invested in period t). The bank then invests the resulting pesos in a long asset that yields a return of R (> 1) in period $t = 2$ for every unit invested in period $t = 0$. The long asset can be liquidated in the intermediate period at a loss. One may think of the long asset as a non-tradable good (e.g the housing sector, for instance), whose returns are denominated in pesos. Since we are considering an EME with lack of financial sophistication and characterised by the absence of a financial market other than the banking system, it is assumed that, in the eyes of foreign investors, the economy lacks credibility to offering debt / deposit contracts denominated in pesos. As a result, all deposit contracts are stipulated in dollars. The bank's problem is to choose a risk-sharing contractual agreement that maximises the expected utility of depositors subject to a zero-profit constraint. It decides on the optimal portfolio between short and long asset in period $t = 0$.

By encompassing features [1]-[5] as discussed in **chapter 6**, there are two main sources of financial vulnerabilities in our setup: there is an *asset-liability maturity mismatch*[1] as in all bank run models - Bank liabilities (deposits) are essentially short-term in nature and liquid while the bank asset (the long asset) is illiquid, with the added feature that there is an inverse relationship between liquidity and viability on the bank's asset portfolio. What our approach adds to the existing literature is that there is also an *asset-liability currency mismatch* in that, while the main assets are denominated in pesos, all its liabilities are denominated in dollars[2]. Thus, as foreign investors will face a liquidity preference shock, they will withdraw from the bank in period $t = 1$ (if they are impatient consumers) or in period $t = 2$ (if they are patient). In either case, the bank promises to meet their contractual obligations in dollars. The two sources of financial vulnerabilities arise because at the time of investment and

[1] The composition of capital inflows was an important factor in a number of financial crises in many EMEs, such as in Thailand in 1997/8 and in Mexico in 1994/5. In both cases, reliance on short-term borrowings to finance huge current account deficits, was the linchpin of financial crises.

[2] It is ostensible that a portfolio choice (i.e the share of wealth held in pesos and in dollar-denominated bonds) depends on the risk-return characteristics of these securities, the structure of shocks and on monetary and exchange rate policies. In our modelling of an EME, we shall assume that *all* deposits are in dollars and *all* assets are in pesos. Thus, the choice of the currency denomination of our asset portfolio is taken as exogeneous in our setup.

decision on optimal portfolio choice, they are zero-probability events. It is in period $t = 1$ that depositors know their types and that the precise nature of aggregate uncertainty in the model becomes known.

Like in **chapter 7**, we begin our analysis by studying the optimality of resource allocation for a theoretical yardstick: the Central Bank as a Social Planner. We show that, under the assumption that the Planner cannot observe the stochastic fundamentals of the economy (in this case, the shadow exchange rate), the best the Planner can do is to offer an approximate truthtelling mechanism that succeeds in insuring against liquidity risks only. Aggregate risks in the form of stochastic variations in the shadow exchange rate are left unhedged and these are reflected in the term structure of demand deposit payments to depositors in that they become contingent on these aggregate risks. This implementation by the Planner results in the Second-Best allocation of resources. The Planner's mechanism succeeds in avoiding a financial crisis under any circumstances. We then study the nature of the allocation under a more decentralised mechanism: that of a banking system. The banking allocation is characterised by positive probability of bank failures. In fact, we are able to pin down the existence of a unique equilibrium threshold in depositors' strategy. When no bank runs occur (depositors receive no news of an impending devaluation), the banking allocation replicates the allocation of the Planner under the Second-Best outcome. When bank runs do occur (depositors receive news of an impending currency devaluation), the allocation becomes Pareto inferior. Thus, while bank runs are devaluation-induced with positive probability, we are interested in constructing a set of asset values for which such a run will eventually result in a banking failure.

More precisely, how do we model the banking allocation and depositors' strategy ? Here, we assume that the exchange rate is initially fixed but we depart from **chapter 7**, in that, depositors are assumed to receive precise interim information about the 'shadow exchange rate' (the true value of exchange rate as dictated by macroeconomic fundamentals). Whatever follows is completely new to the literature. We construct an equilibrium threshold, which will delineate depositors' actions as a function of their precise interim information. If depositors receive precise information that the current peg is overvalued, the resulting currency devaluation will result in depositors withdrawing their deposits immediately. However, whether a bank run will occur or not will depend on the value of the bank's stochastic assets. We show that there is a unique threshold of the shadow exchange rate above which, a currency devaluation occurs and below which it does not occur. We are thus capable of exploring the circumstances under which a currency devaluation (resulting in a bank run) will eventually lead to a banking failure for a simulated range of the bank's fundamentals within a well-defined theoretical context. We can thus confirm the nature of the conduit through which a crisis flows from the foreign exchange sector to the banking sector.

The contributions enshrined in **chapters 7** and **8** are essential to the debate on the welfare properties of the effectiveness of various policy measures and choice of exchange rate regimes. As we will explicate, a currency crisis may cause a banking crisis (and failure) through the effects of a currency devaluation on the balance sheets of banks characterised by liability dollarisation. Resolving a currency crisis may, by itself, lead to trouble in the banking sector if it requires massive interest rate hikes[3] or massive foreign exchange intervention to defend the peg. In our environment, the former works by affecting the assets of banks and by resulting in stochastic variations in banks' asset values. As we studied in the previous chapter, stochastic variations in banks' fundamentals may result in information-induced banking failures. The latter works by depleting foreign exchange reserve level of the economy and by resulting in possible currency devaluation and eventual devaluation-induced banking failures. Thus, while defending the peg may stabilise the exchange rate, this may

[3] Interest rate hikes may fragilise banks by inducing adverse selection and moral hazard in their asset portfolio.

come at the cost of destabilising the banking system. We show in **chapter 7** that information-induced banking failures may result in lower welfare loss than devaluation-induced banking failures. Thus, our framework advocates the use of interest rates rather than foreign exchange intervention as ways of defending the peg.

We also intend to use our framework to shed light on the debate on the most appropriate form of the exchange rate regime and the accompanying safeguards that may be adopted by an EME - where the appropriate form of the exchange rate regime is the one that minimises the probability of either form of crisis and that helps restore the Planner's Second-Best solution. The current macroeconomic paradigm suggests the adoption of exchange rate regimes based on exogenous factors (e.g on the ability of the regime to anchor inflationary expectations successfully). Furthermore, in the specific context of an EME characterised by liability dollarisation and by influx of foreign capital as deposits, the current macroeconomic paradigm struggles to provide some insight about the most appropriate form of exchange rate regime. Liability dollarisation typically warrants a regime that is different from pure floats[4]. Integration in world capital market warrants a regime that is different from pegs[5]. As such, due to these offsetting factors, current macroeconomic models fail to offer temptative suggestions about the appropriate form of exchange rate regime in EME.

Our model, deeply rooted in financial intermediation, differs from the current paradigm in that we can contribute to the debate on choice of exchange rate regimes based on the ability of the regime to minimise the probability of banking and currency crisis (twin crisis) occurring. We bring value-added to the debate about the appropriate design of exchange rate regimes by being able to compare the effectiveness of various structures on welfare theoretic terms. In particular,

[4] Due to the 'fear of floating' argument that is so common in EME circles.

[5] Due to speculative pressure instability and monetary policy impotency that accompany soft pegs.

our model suggests that if the aim of the policymaker is to keep exchange rate stable, it may do so by using interest rate policy rather than foreign exchange reserve policy to defend the peg. Interest rate policy, by affecting a bank's stochastic fundamentals, may result in information-induced banking failures. Foreign exchange intervention policy, by leading to currency devaluations through depletion of foreign reserves, may lead to devaluation-induced banking failures. An important corollary of our approach is to show that devaluation-induced banking failures may result in greater welfare loss than information-induced banking failures. Thus, while both policies succeed in keeping the exchange rate fixed at the cost of destabilising the banking system, interest rate policy results in lower welfare loss than foreign exchange intervention. Thus, interest rate policy seems to be a more prominent intervention for Central Bank's policy. Conversely, if the aim of the policymaker is to pre-empt the occurrence of both crises (i.e eliminate the likelihood of both crises), some state-contingent structure in the exchange rate regime is important. The aim of the state-contingent structure is to enable restore the Planner's second-best allocation. A few propositions are studied e.g crawling peg systems, capital controls, managed floating regime.

The rest of the chapter is organised as follows: **Section 8.2** considers the interraction between banks, the foreign exchange market and the Central Bank as a mechanism, designed to bring optimal allocation of resources. We show that a banking system is Pareto inferior to the central planner which offers the second-best solution because it is prone to devaluation-induced runs from the depositors in some states of the world, whereas the central planner does not suffer from that syndrome. In **section 8.3**, we document on the mechanics of a crisis flow from the foreign exchange sector to the banking sector. **Section 8.4** highlight some conjectural applications of our contribution to the areas of optimal taxation design and contingent liabilities. Furthermore, we discuss the implications of our paradigm to the choice of the exchange rate regime debate in **section 8.5.** Finally, **section 8.6** concludes.

8.2 Mechanism Design Problem for an EME

The timeline of events is as in section 6.2.4 in **chapter 6**. We now assume that the interim news that depositors receive, concern the shadow exchange rate only. We still take the bank's portfolio performance to be stochastic but depositors are no longer assumed to receive interim signals about the bank's portfolio performance[6].

Concept of a shadow exchange rate: Let e denote the shadow exchange rate and $\bar{e}$ denote the actual exchange rate. The shadow exchange rate, e, is a fictitious concept taken to mean the underlying strength of the currency as dictated by external or domestic macroeconomic influences or by any speculative pressure from the financial markets. Here, we take e to be a stochastic element, with probability density, $f(e)$ and with full support on $[0, \infty]$. Given the randomness of the shadow exchange rate, there is a weak segment of the distribution that tells depositors that the currency is facing speculative pressure (and, thereby, looks set to devalue) and a strong segment of the distribution that suggests otherwise. We demonstrate the existence of such segments by rationalising the existence of a unique e^*. Any $s \in [0, e^*]$ gives depositors news that the currency is not under speculative pressure - in which case, no devaluation occurs (i.e the actual exchange rate remains fixed at $\bar{e} = 1$). On the other side, any $s \in (e^*, \infty]$ gives to depositors news that the currency is under immense speculative pressure - in which case, a devaluation occurs and the exchange rate is dictated by market forces and takes the same profile as the shadow exchange rate (i.e $\bar{e} = e$).

Claim 8.1: *Let e denote the shadow exchange rate and let $\bar{e}$ denote the actual exchange rate. Thus, $\bar{e}$ takes the following profile:*

[6] Other features of R still hold as in chapter 5: it is measured in pesos and, if liquidated, will yield a fixed amount γR, $\gamma < 1$. Note that R can be anywhere between 0 and $\frac{\kappa(1-\lambda)}{\gamma\lambda(1-\kappa)}$. We shall later see that the specific range of the values of R will matter when discussing the circumstances under which a currency crisis will lead to a banking crisis.

$$\bar{e} = \left\{ \begin{array}{cc} 1 & \text{if } s \in [0, e^*] \\ e & \text{if } s \in (e^*, \infty] \end{array} \right\}$$

8.2.1 Anatomy of Financial Fragility

The following argument / example demonstrates that, due to asset-liability unhedged currency risks, a devaluation will produce a balance sheet effect by affecting the investment portfolios for periods $t = 1$ and $t = 2$. By so doing, the amount available as payment to depositors will be reduced, as per the above claim.

Example 8.1: ***(Devaluation-Contingent Payoffs)*** *Assume that R has a bernoulli distribution*[7]*: R_L with probability θ and R_H with probability $1-\theta$, where $0 < \theta < 1$ and $0 < R_L < R_H$. Let's assume that the ex-ante exchange rate is normalised at 1. Due to uncertainty in the return of the risky technology, the amount paid in dollars in period $t = 2$, is contingent on the particular realisation of R and on the expected exchange rate.*

Let $\tilde{c}_2$ be the stochastic payment made to depositors if $R = R_H$ and if there is no currency devaluation. If we are in a state of the world in which $R = R_L$, then the bank is declared insolvent in period $t = 2$ and will be assumed to be able to pay only part of its promised payment. Thus, if there is no devaluation and if $R = R_H$, then $\tilde{c}_2 = c_2$. On the other hand side, $\tilde{c}_2 = c_2\left(\frac{R_L}{R_H}\right)$ if $R = R_L$ (i.e depositors receive only a fraction $\frac{R_L}{R_H}$ (< 1) of the promised payments in the bad state of the world.

The analysis, so far, has assumed that the exchange rate remains fixed throughout our experiment. To see how a change in the expected exchange rate affects the promised contractual payments to depositors, let's assume that there is a devaluation in period $t = 2$ from 1 to e_2 $(e_2 > 1)$. In this case, investors

[7] Exceptionally, we assume that R can take two values here, to prove the argument.

receive a proportion $\frac{R_H/e_2}{R_H/1} = \frac{1}{e_2}$ *of the promised payment if* $R = R_H$, *while they receive* $\frac{R_l/e_2}{R_H/1} = \frac{R_L}{e_2 R_H}$ *of their payments if* $R = R_L$.

Thus, with devaluation, $\tilde{c}_2 = \frac{c_2}{e_2}$ *if* $R = R_H$, *while* $\tilde{c}_2 = c_2\left(\frac{R_L}{e_2 R_H}\right)$ *if* $R = R_L$. *In general,* $c_2\left(\frac{R_L}{e_2 R_H}\right) < \frac{c_2}{e_2} < c_2$.

While the payoffs to depositors will unambiguously be reduced, irrespective of the realisation of the risky technology, a devaluation reduces the payments to late depositors relatively more in the bad state than in the good state

8.2.2 Second-Best Allocation (Central Bank acts as Social Planner)

Now, assume that the Central Bank is still the supra-national authority that reallocates resources within the banking industry but that it cannot observe the realisation of e. The optimisation problem boils down to:

$$\max_{c_1} \; E[\lambda U(c_1(e)) + (1-\lambda) U(c_2(e))]$$

s.t

$$\lambda c_1(e) \leq \kappa$$

$$c_2(e) = \frac{(1-\kappa)\frac{R}{e} + \kappa - \lambda c_1(e)}{1-\lambda}$$

$$\int_0^\infty c_1(e)\; f(e)\; de \leq \int_0^\infty c_2(e)\; f(e)\; de$$

Claim 8.2: *The optimal solution*[8] *results in a state-contingent term structure of demand deposit repayment of the following form:*

[8] Technically, $c_2(e) = \frac{(1-\kappa)R}{(1-\lambda)e}$ but we have assumed $e = 1$

$$c_1(e) = c_2(e) = (1-\kappa)\frac{R}{e} + \kappa \qquad\qquad e > e^{*}$$ [9]

$$c_1(e) = \frac{\kappa}{\lambda}, \quad c_2(e) = \frac{(1-\kappa)R}{1-\lambda} \qquad\qquad e \leq e^{*}$$

$$\textit{with } e^{*} = \frac{\lambda(1-\kappa)R}{\kappa(1-\lambda)}$$

8.2.3 Banking Allocation

Remark 8.1: *(***Depositors' Strategy***) The strategy of depositors is a mapping from their type space (information about liquidity preference and interim news about the shadow exchange rate) to their action space (i.e to stay or to withdraw)*

Given the notion of a depositor's strategy, we move on to describe the withdrawal rule:

Remark 8.2: *(***Withdrawal Decision Rule***) Given their strategy as described above and the existence of devaluation-contingent payoffs, depositors all choose to withdraw if* $e > e^{*}$ *(dominant to withdraw) and choose to stay if* $e \leq e^{*}$ *(dominant for all depositors to stay).* $e^{*} = \frac{\lambda(1-\kappa)R}{\kappa(1-\lambda)}$.

Using similar analysis to that of the last chapter, the banking contract allocation can thus be viewed as a sum of two elements:

$$\max_{c_1,\,\kappa} \int_{e^{*}}^{\infty} \Psi\, U(c_1(e))\; f(e)\; de \;+ \int_{0}^{e^{*}} \left[\lambda U(c_1(e)) + (1-\lambda) U(c_2(e))\right] f(e)\; de$$

[9] The threshold is computed as follows: Let $\frac{\kappa}{\lambda} = \frac{(1-\kappa)\frac{R}{e^{*}}}{1-\lambda}$ at the point of indifference between consuming early and late. This boils down to: $e^{*} = \frac{\lambda(1-\kappa)R}{\kappa(1-\lambda)}$. Note that here, when $e > e^{*}$, the risky asset does not need to be liquidated. Since the Central Bank can reshuffle resources costlessly, it can bring some of its short-asset forward to supplement the low returns in period $t = 2$ whenever $e > e^{*}$.

s.t

$$\lambda c_1(e) \leq \kappa$$

$$c_2 = \frac{(1-\kappa) R}{e(1-\lambda)}$$

where $e^* = \frac{\lambda(1-\kappa)R}{\kappa(1-\lambda)}$, $\int_{e^*}^{\infty} \Psi\, U(c_1(e))\, f(e)\, de$ is the element of the banking contract (Ψ[10] denotes the proportion of those who receive full repayment under the sequential service constraint) that makes the bank vulnerable to the risks of a currency devaluation and $\int_0^{e^*} [\lambda U(c_1(e)) + (1-\lambda) U(c_2(e))]\, f(e)\, de$ is the element of the banking contract that induces truthtelling behaviour. Thus, if the shadow exchange rate moves in the $[0, e^*]$ region and depositors receive a perfect signal of it, the currency is viewed as strong by the financial markets. Thus the exchange rate stays fixed. In this case, payments to patient depositors amount to $\frac{(1-\kappa)R}{1-\lambda}$ (with $e = 1$) and those to impatient depositors amount to $\frac{\kappa}{\lambda}$. Truthtelling behaviour is induced since $\frac{(1-\kappa)R}{1-\lambda} > \frac{\kappa}{\lambda}$. Conversely, if the shadow exchange rate moves in the $(e^*, \infty]$ region, the currency is viewed as being fundamentally weak and subject to immense speculative pressure. All depositors receive a perfect interim information of this and they all withdraw in period $t = 1$, with only proportion Ψ receiving full payment, as promised by the contract.

[10] $\Psi = \frac{\kappa+\gamma(1-\kappa)\frac{R}{e}}{c_1^*}$. Note that $\Psi < \Xi$ (i.e $\frac{\kappa+\gamma(1-\kappa)R}{c_1^*}$)

FIGURE 8.1: Shadow Exchange Rate Concept

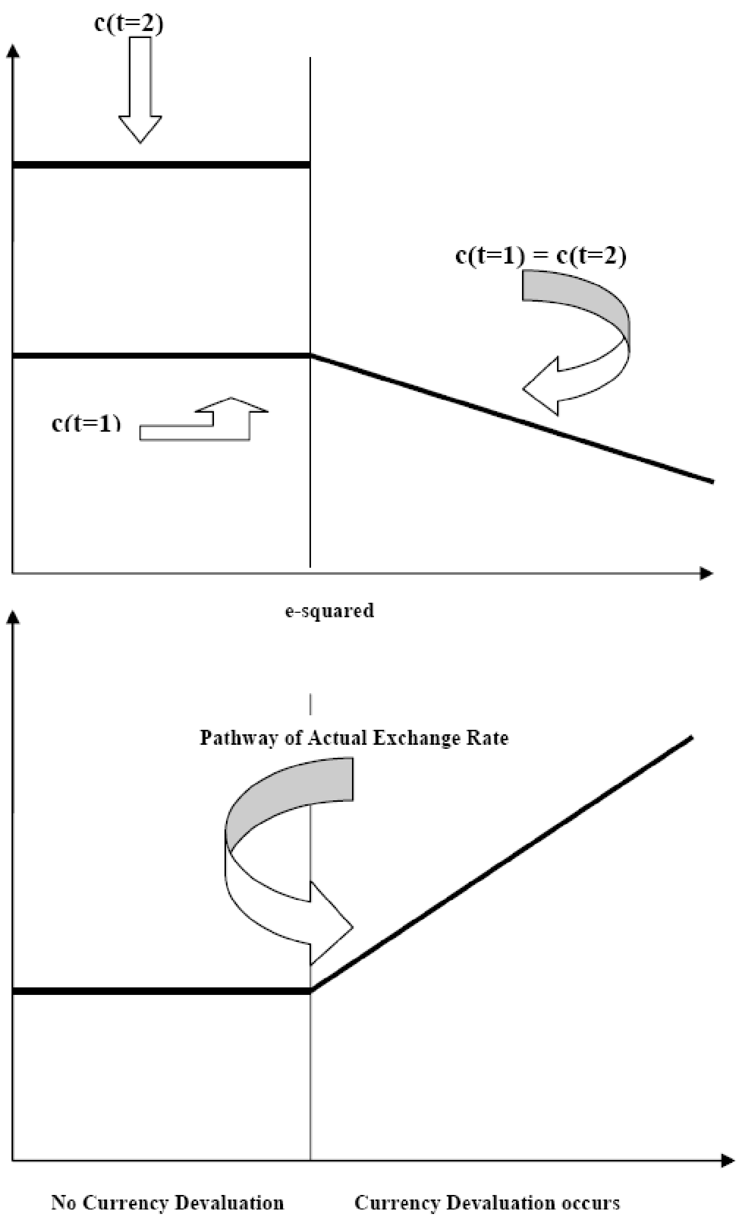
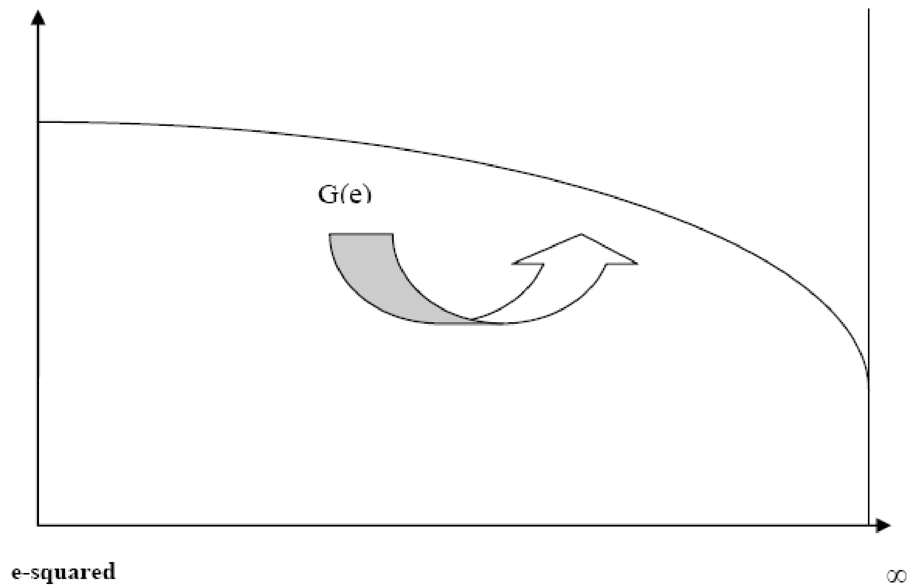


FIGURE 8.3: Proportion of Foreign Depositors Withdrawing Early in the Presence of Sequential Service Constraints



8.3 Dynamics of Financial Crises

Definition 8.1: ***(Currency Crisis)***[11] *In the presence of a perfect signal about the shadow exchange rate, we define a currency crisis as a situation in which depositors receive news about an imminent devaluation of the currency i.e* $s \in (e^{*}, \infty]$.

[11] Frankel and Rose (1996) in "Currency Crashes in an Emerging Market: Empirical Indicators", define a currency crisis as one in which the exchange rate depreciates in nominal terms by over 25% in a year, along with a 10% depreciation from the previous year. A sidenote: the latter condition is taken so as to exclude the large long-term depreciation trends of high-inflation economies. The problem with viewing a currency crisis from the vantage point of nominal depreciation is that it "excludes episodes in which the currency came under immense speculative pressures but was successfully averted by the Central Bank's foreign exchange intervention or by interest rate policy." As such, an index of speculative pressure may be a more accurate description of a currency crisis.

The literature identifies three theoretical channels of transmission from a currency crisis to a banking crisis: (*interest rate channel*) Resolving a currency crisis often requires Central banks to increase interest rates sharply to maintain confidence in the peg and to ward off speculative attacks on the currency; this may fragilise the banking system by distorting financial intermediation[12]; (*balance sheet channel*) A currency crisis (e.g a devaluation) may fragilise the balance sheet of banks that suffer from unhedged currency mismatches i.e banks have liabilities predominantly denominated in foreign currencies - this balance sheet effect may be strong enough to lead depositors to anticipate the bank's failure and to run on their banks. On the same wavelength. the crisis creates a contingency liability for the government because it is forced to bailout the bank when the effects of a currency devaluation weaken the bank's balance sheet. Such interventionist schemes can only quicken the evaporation of foreign reserves, thereby making the problem more self-sustaining; (*foreign reserve channel*) Alleviating a currency crisis pressure by using foreign exchange intervention to defend the peg, may deplete foreign exchange reserves and may lead to a self-fulfilling currency crisis which, in turn, affects the balance sheet of banks that are engaged in liability dollarisation.

Since we have assumed that (foreign) depositors receive interim about the shadow exchange rate, we use Figures 8.4 and 8.5 (please turn next page) as the standard benchmark case. Here, e^* and R^* represent the archetypal thresholds for the shadow exchange rate and the bank's portfolio purformance respectively.

[12] As mentioned in the introduction, higher interest rates may lead to adverse selection (i.e asymmetric information cases when only bad borrowers are willing to borrow at the going (higher) interest rates) and moral hazard (i.e banks are willing to engage in riskier ventures because they reap the full upside benefits of these gambles but do not suffer the downside risks. Limited liability constraints, deposit insurance and relaxation of controls over bank asset holdings, are all possible reasons validating this "gamble for resurrection". See Mishkin (1996) for more on adverse selection and moral hazard in financial markets.

FIGURE 8.4: Performance Space when Interim Information is about Idiosyncratic Fundamentals Only

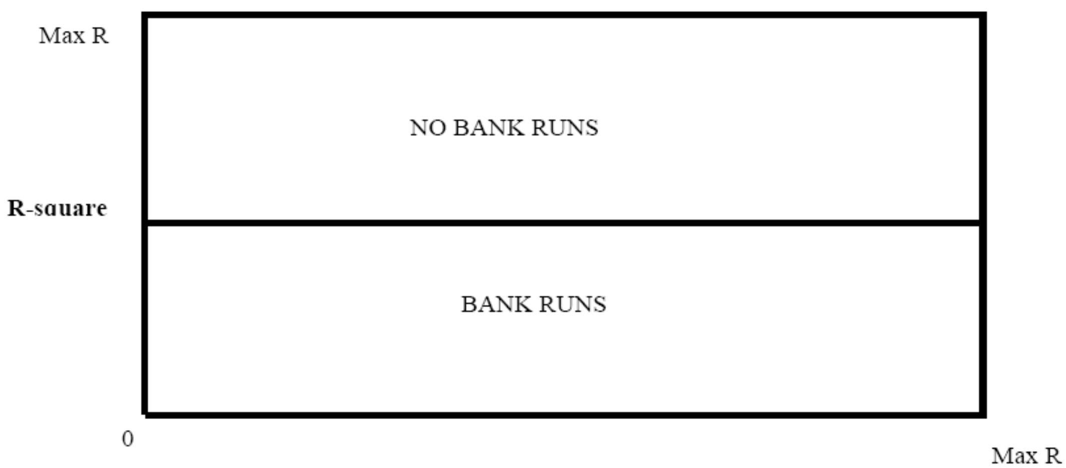
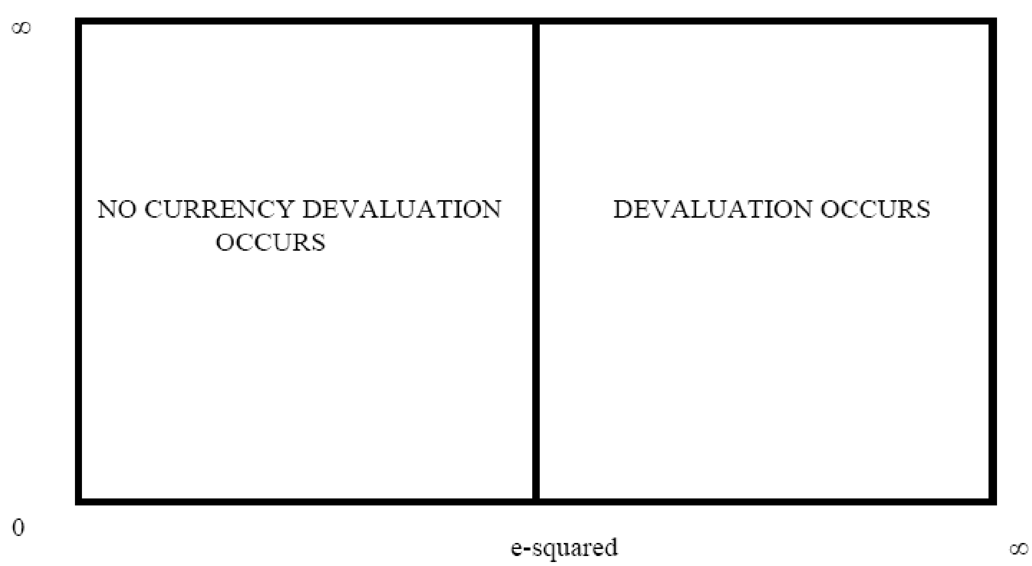


FIGURE 8.5: Performance Space when Interim Information is about Shadow Exchange Rate Only



We are interested in analysing a situation in which a currency crisis (or devaluation), by its own, creates and leads to a banking crisis, where no such banking crisis would have occurred otherwise. The transmission mechanism from currency crisis to banking crisis will be through the balance sheet effects. In order to isolate cases in which a currency crisis can, by itself, generate a banking crisis through balance sheet effects, we consider a situation in which there is no bank run to begin with (i.e $R > R^*$ - the upper segment in Figure 8.4). Thus, we assume that the bank's fundamentals are "strong" to begin with. Now, let us assume that depositors receive an interim information about the shadow exchange rate and that they expect it to depreciate. In Figure 8.5, we are now looking at the rightward segment of the graph (i.e $e > e^*$). To consider how a currency crisis may, by itself, lead to balance sheet effects, it is our intention to construct a set of values for the bank's stochastic fundamentals and explore the circumstances under which, balance sheet effects will occur.

With interim information about the shadow rate, the point of indifference between staying and withdrawing, upon receiving information about the shadow exchange rate only, was condition: $\frac{\kappa}{\lambda} = \frac{(1-\kappa)R}{(1-\lambda)e^*}$ where $e^* = \frac{\lambda(1-\kappa)R}{\kappa(1-\lambda)}$. Here, when $e > e^*$, $\frac{\kappa}{\lambda} > \frac{(1-\kappa)R}{(1-\lambda)e}$ and all depositors present themselves to the bank. To analyse the circumstances under which a currency crisis, by itself, leads to a banking crisis, we consider a hypothetical case in which depositors receive interim information about the shadow rate but that the value of the bank's portfolio investment will change to a new fixed amount. To do this, we consider a benchmark case in which, initially, $R = R^*$ and $e = e^*$. The point of indifference between staying and withdrawing is thus: $\frac{\kappa}{\lambda} = \frac{(1-\kappa)R^*}{(1-\lambda)e^*}$. Thus, in Figures 8.4 and 8.5, we are currently on the threshold lines for the shadow exchange rate and for the portfolio investment. As stated above, our aim is to construct a range of values of R for which a currency crisis may, by its own, lead to a banking crisis where none would have existed otherwise. Thus, we allow e to depreciate i.e $e > e^*$. By how much must the stochastic R rise above R^* in order to ensure that investment (evaluated in dollars) remains unaffected?

Starting from the point of indifference, it is clear that when $e > e^*$ and with R still remaining at R^*, $\frac{\kappa}{\lambda} > \frac{(1-\kappa)R^*}{(1-\lambda)e}$. Thus, R must rise to $\frac{eR^*}{e^*}$ (we denote this $\ddot{R}$) in order to take us back to the original point of indifference between staying and withdrawing i.e $\frac{\kappa}{\lambda} = \frac{(1-\kappa)\frac{eR^*}{e^*}}{(1-\lambda)e} = \frac{(1-\kappa)R^*}{(1-\lambda)e^*}$. Thus, as long as $R^* < R < \ddot{R}$, a devaluation affects the investment value of the bank's portfolio (measured in dollars) and results in balance sheet effects. The change in the value of R from the originally fixed R^* to the new fixed R (labelled R^{fixed}, where $R^* < R^{fixed} < \ddot{R}$) is not strong enough to offset the devaluation effect. Thus, when $e > e^*$and $R^* < R^{fixed} < \ddot{R}$, the bank's portfolio investment is affected and consuming early yields a higher payoff than consuming late (i.e $\frac{\kappa}{\lambda} > \frac{(1-\kappa)R}{(1-\lambda)e}$). All depositors, given their strategy, will run to the bank to withdraw. If R lies above $\ddot{R}$ (i.e where $\ddot{R} \leq R^{fixed} < \infty$), the fixed new value of investment is strong enough to outweigh the effects of the devaluation - investment (evaluated in dollars) is unaffected and $\frac{\kappa}{\lambda} < \frac{(1-\kappa)R}{(1-\lambda)e}$. No bank runs result as patient depositors decide to stay on the bank.

To summarise, in Figure 8.6 (please turn over), the first quadrant depicts the situation in which a bank run occurs just because the currency has been devalued. A necessary condition for this is that R is above R^* but "sufficiently low". Note that such a run would not have occurred otherwise. This quadrant is the one of theoretical interest when we shall examine the implications of a devaluation for contingent liabilities of the government. Note that, if no devaluation occurs (i.e $e \leq e^*$), there will be no bank runs *as long as depositors receive the interim signal about the shadow exchange rate only.*

In Figures 8.7 and 8.8 (please turn over), we demonstrate that, starting from a point in which $R = R^*$ and $e = e^*$, a currency devaluation raises the threshold of the bank's performance from R^* to $\ddot{R}$. The larger the currency devaluation is, the higher is the new threshold of the bank's performance. The shaded area in Figure 8.8 was, prior to the devaluation effect, a region of no-bank run. Now,

FIGURE 8.6: Transmission Mechanism From Currency Crisis (cause) to Banking Crisis

CAUSE / EFFECT	**Devaluation occurs (e > e*)**	**Devaluation does not occur (e ≤ e*)**
Bank Run occurs	If R is above R^* but "sufficiently low" (**Note 1**)	Nil
Bank Run does not occur	If R is above R^* but "sufficiently high" (**Note 2**)	Nil

Note 1: $R^* < R < R$
Note 2: $R < R < R_{MAX}$

FIGURE 8.7: Performance Space in the Presence of Stochastic Idiosyncratic Fundamentals and Stochastic Shadow Exchange Rate

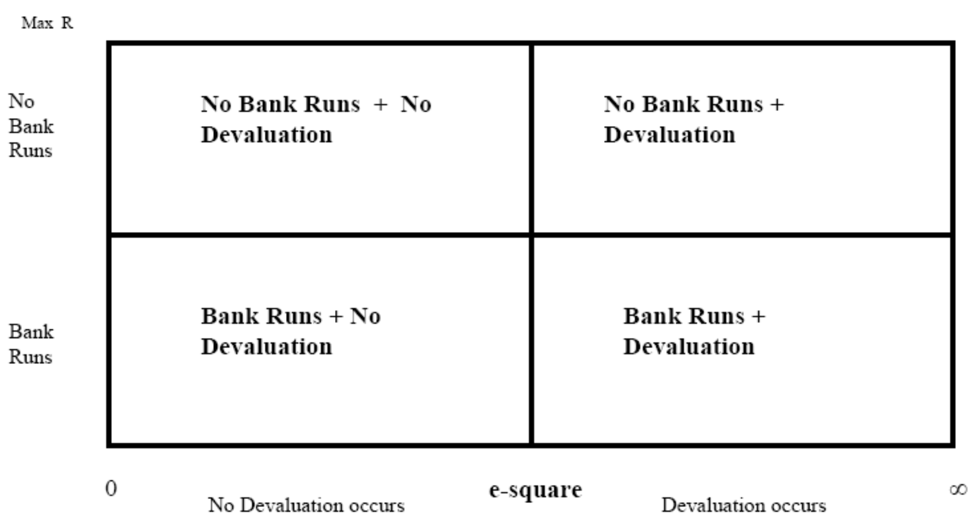
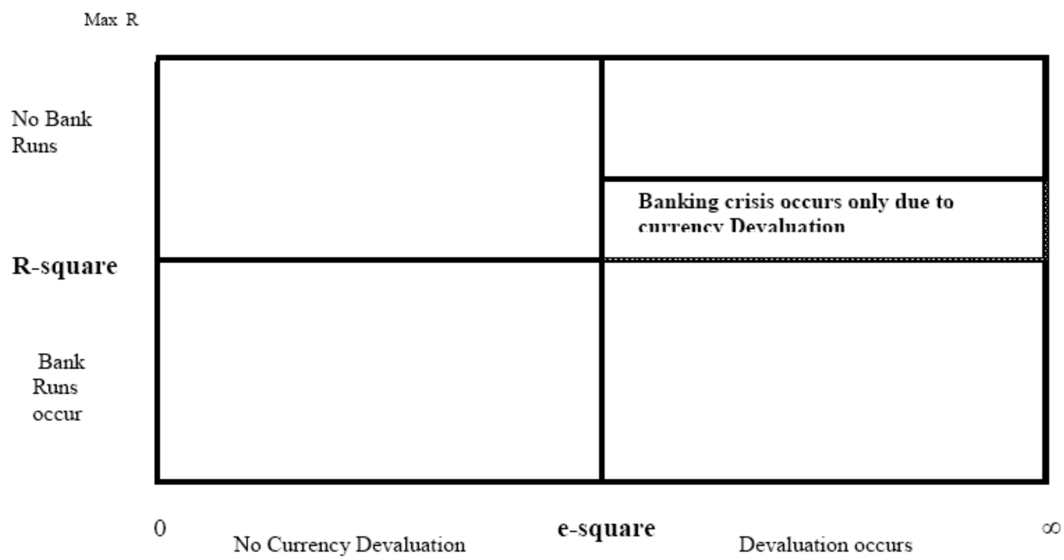


FIGURE 8.8: Graphical Description of Transmission from Currency Crisis to Banking Crisis



with the effect of a currency devaluation, the shaded area represents a case of the devaluation effect leading to a balance sheet effect and eventually to a banking crisis. Thus, the shaded region represents a case of a banking crisis occurring exclusively due to the occurrence of a currency crisis, when none would have occurred otherwise.

Corollary 8.1 *A devaluation-induced banking crisis, due to "balance sheet effect", occurs if and only if:*

[1] $e > e^*$ *where* $e^* = \frac{\lambda(1-\kappa)R}{\kappa(1-\lambda)}$

[2] $R^* < R^{fixed} < \ddot{R}$ *where* $R^* = \frac{c_1-\kappa}{1-\kappa}$ *and* $\ddot{R} = \frac{eR^*}{e^*} = \frac{e(c_1-\kappa)}{e^*(1-\kappa)}$

Condition [1] *is necessary for the occurrence of devaluation. Condition* [2] *is sufficient for the 'devaluation' effect to damage the balance sheet of the commercial bank, after R has changed from R^* to R^{fixed}. The co-existence of both conditions leads to a banking failure that is exclusively due to currency crisis and is depicted in Figure 8.8.*

8.4 Some Applications: Analytical Afterthoughts about Policy Implications

8.4.1 Revaluation and the IMF Recipe

The main stance of the paper that a currency crisis may, for a certain range of fundamentals, induce a devaluation-induced banking crisis through balance sheet effects, suggests that a revaluation policy can be viewed as a *bank run preventing device* in many emerging market economies. Because of the negative impact that devaluation has on a bank's balance sheet , it follows that a revaluation policy will have an opposite effect and will increase the bank's net worth. Revaluation policy was viewed as the IMF's recipe in the wake of the Asian crisis of 1997. The IMF proposed interest rate hikes as policy measure. The balance sheet effect means that the setting of monetary and interest rate policy in an EME, is a matter of great debate among economists. In the wake of the East Asian crisis of 1997, the IMF, spearheaded by Stanley Fischer, contended that restoring confidence in the currency value and reversing the outflow of capital were mandatory. Evidence suggests that the IMF was "unqualifiedly right in its insistence on high interest rates at the front end of economic stabilization." The IMF's stance was criticized by Joseph Stiglitz, then chief economist at the World Bank, but received resusitation by Krugman (1999), who argued that it was balance sheet vulnerability that prevented a relaxed monetary stance and currency devaluation in East Asia.

8.4.2 Economics of Contingent Liabilities - Areas for future Research on Optimal Taxation Rules

Banking crises can be very costly, both in the fiscal costs of re-structuring the financial sector and restoring public confidence and also in preventing the financial system from operating effectively. The resolution costs of banking crises in many EMEs have been over 40% in Argentina and Chile in the 1980s. Balance sheet effects that lead to the existence of bank runs, when none would have existed otherwise, leads to contingent liabilities for the public outlay. Contingent liabilities have implications for the Central Bank. To highlight a particular example, lets assume that the Central Bank is the manager of the government's debt portfolio. We are interested in the first quadrant of Figure 8.7 i.e the part at which devaluation, by itself, leads to a bank run when there would have been no bank runs otherwise.

Definition 8.2: (**Contingent Liabilities**) *Liability to the government 's public finance that occurs in some states of the world but not in other states.*

Contingent liabilities represent liabilities that did not exist before but that get created artificially due to some indirect effects. The effects of a currency devaluation on the balance sheet of banks, represent a contingent liability to the Central Bank because there was nothing wrong with the bank's performance to begin with. It is the indirect effect of currency devaluation that leads to balance sheet effects and that weakens the banking system - thereby, urging the policymaker to step in and to earmark public funding as part of a bailout strategy. Thus, the liability is incurred in those states of the world in which a currency devaluation occurs but not in other states[13].

The effects of a currency devaluation on public finance through the creation of contingent liabilities is a challenge for debt sustainability and debt management. The main conundrum that policymakers face is whether a *fully-funded tax system* can contain the contingent liabilities and achieve the first and second-best outcome ? As in microeconomic model for insurance, in the 'no devaluation' state of the world, the commercial bank is assumed to pay an interest to the Central Bank. In the 'devaluation' state of the world, the com-

[13] From this exposition, it becomes clear as to why bailing out a failed bank, when the origins of a crisis lie in the banking sector itself, cannot be regarded as contingent liabilities. This is because such liabilities would have occurred in all states of the world ($R \leq R^*$).

mercial bank pays interest to the Central Bank as usual but the Central Bank reimburses the full amount needed to keep promised payment as stipulated in the bank contractual agreement. One interesting question pertaining to this insurance scheme will be on its appropriate design and on the prerequisite incentives needed for agents to ensure the fulfillment of its two main objectives: (*fully-funded tax system):* the Central Bank charges a tax in all states of the world , which is high enough to fully fund the bank's resources to make a full expected payout in the case of the state of the world going bad; (*sustainability of bailout programs):* the amount disbursed when the state of the world goes bad, must be enough to pay commercial bank, such that it can fulfill its promised contractual payments to depositors over periods $t = 1$ and $t = 2$.

From the point of the policymaker**,** the aim is to raise sufficient revenue whilst ensuring that the system is fully-funded and sustainable. The bank's aim is to maximise the welfare of depositors subject to:

[**1**] Its resource constraints in periods $t = 1$ and $t = 2$

[**2**] Its participation constraints i.e its incentive to join the taxation scheme

[**3**] Its investment strategically chosen is to maximise the expected profits

[**4**] Its taxation being fully-funded and sustainable for the policymaker

One interesting area of future research is to focus on the design of this bailout scheme and on the nature of the optimal taxation that is required as a result.

8.5 Design of Exchange Rate Regime for an EME - Fixed vs Floating Debate

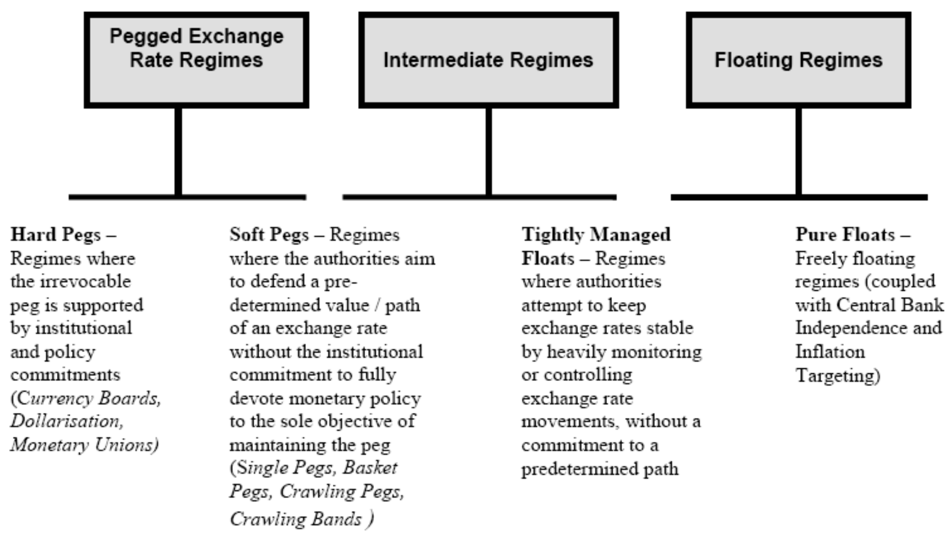
We now turn to the study of the implications of our paradigm of **chapters 7** and **8** for the choice of exchange rate regimes. We combine the knowledge accummulated from these two chapters to address this crucial issue about exchange rate regimes. While we do not plan to develop any new model, we just intend to use our model predictions and findings to contribute to the debate about design of exchange rate regime. The choice of an appropriate exchange rate regime[14] for a country is one of the most important decisions for a government to make, given the fact that the exchange rate regime will dictate the form of monetary policy of the Central Bank (and may implicitly affect the fiscal stance of the government) and will have consequences for financial and real variables that relate to businesses and households. Figure 8.9 (please turn over) provides a broad classification of exchange rate regimes in practice.

The choice of exchange rate regimes has been debated by macroeconomists over decades. The earliest (and probably, most successful) attempt has been the Mundell-Fleming model[15]. The simple Mundell-Fleming model extends the IS-LM framework to allow for open economy considerations. Assuming perfect capital mobility (and implicitly that home interest rates being constrained by the world interest rate), the model studies how different monetary and real shocks affect output under different exchange rate regimes. The 'success' of an exchange rate regime is measured by its ability to minimise output fluctuations in the presence of these exogenous shocks. In the presence of monetary shocks, a fixed exchange rate regime has an embedded mechanism to minimise output fluctuations. Thus, a fixed regime is preferred. In the presence of real shocks, a

[14] The most important factors suggested by the macroeconomic paradigm include: [*a*] the degree of integration of the domestic financial system in the international financial system; [*b*] the degree of domestic financial sophistication; [*c*] ex-ante inflation rate and ex-post credibility in fighting inflation; [*d*] level of international reserves; [*e*] wage and price flexibility; [*f*] labour mobility; [*g*] pattern and degree of trade with partner country; [*h*] symmetry of external shocks with that of the partner country; [*i*] domestic monetary v/s real (including supply) shocks. Factors (e)-(h) are actually factors that determine whether it makes more sense for a group of countries to form a currency area. See **Figure 8.11 (a)** for an illustration.

[15] The Mundell-Fleming model appears in any standard Macroeconomics textbook. Our referencing here follows the textbook version.

FIGURE 8.9 : Classification of Exchange Rate Regimes



flexible regime minimises output fluctuations[16]. Figure 8.10 (please turn over) summarises the main findings of the simplified Mundell-Fleming model for a small open economy.

" (The Mundell-Fleming model) still serves as the default model for most policy-makers. Further, the predictions of the model are so striking and intuitive that they continue to represent the benchmark against which the predictions of newer models are tested" (Andrew K. Rose[17]). Despite being a major workhorse for policymaking in an open economy, the Mundell-Fleming model has a number of limitations when it comes to choice of exchange rate regimes.

[1] It assumes the 'best regime' is the one that minimises the effect of some exogenous shock on output. While this approach may receive theoretical support, in practice, countries pay attention to more useful macroeconomic and financial considerations when they decide on their exchange rate regimes. Fig-

[16] Again, the interested reader is requested to read any (good) undergraduate textbook in Macroeconomics for more on the Mundell-Fleming model.

[17] Quoted on Robert Mundell's website.

FIGURE 8.10 : Simple Mundell-Fleming Model

Assumption: Small Open Economy with Perfect Capital Mobility

	Flexible Exchange Rate Regime	**Fixed Exchange Rate Regime**
Monetary Shocks	Output fluctuates	No effect on Output
Real Shocks	No effect on Output	Output fluctuates

ure 8.11 (pp 279) summarises these main considerations. We will try to use our paradigm to offer some suggestions about the choice of exchange rate regime, based on some of these more realistic considerations.

[**2**] A major flaw underpinning the Mundell-Fleming model is that it ignores the microfoundations of financial markets or of financial intermediaries. This is another weakness that we will try to address, using the specificities of our paradigm, to throw light on the debate. Thus, in our approach, we will endeavour to measure the "success" of an exchange rate regime on its ability to prevent a bank run and to help restore the Planner's Second-Best solution.

[**3**] The Mundell-Fleming model does not allow for liability dollarisation and for an analysis of the implications of liability dollarisation for conventional policy. Some policies suggested by the paradigm, may not necessarily hold in the presence of liability dollarisation. The structure of a bank's balance sheet characterised by debt contracts denominated in foreign currency and assets denominated in the home currency, means that the bank will be wary of the impact of a currency devaluation on its balance sheet. Depending on the nature and structure of economic shocks a country faces, conventional macroeconomic paradigm sometimes dictates that expansionary monetary policy (and the resulting currency depreciation) is a necessary response to these adverse shocks.

But with a high proportion of liabilities denominated in foreign currencies, a weaker local currency can wreck the balance sheets of local banks[18]. Indeed, as we demonstrated in example 8.1, a currency devaluation weakens the bank's balance sheet and, if anticipated by depositors, may lead to an actual bank run. Attempts by the Central Bank to bailout the commercial bank by using reserves of international currency, will only precipitate the devaluation.

[4] For an EME such as the one we study, conventional paradigm will fail to contribute to the debate about the choice of an appropriate exchange rate regime since there are opposing forces dictating the choice of the regime. On the one hand, we have complete financial liberalisation due to unrestricted inflow of foreign depositors who invest in the banking system on a short term basis. On the other hand, balance sheets of banks are characterised by liability dollarisation. The former argument warrants a move away from a fixed exchange rate regime to embrace a floating regime since pegging would invite trouble for the country's economic management: the country's ability to control its monetary policy will be lost and there will be invited speculative pressures on the cur-

[18] Balance sheet effects constitute one of the key reasons as to why a currency devaluation may be contractionary. Other reasons include: [1] **deflation** - the deflationary stance that accompanies devaluation that may more than offset the positive effect of the devaluation - deflation, itself, may either increase real interest rate or increase the real value of any domestic currency indebtedness and lead to banking fragility, [2] **income redistribution** - redistributive effects from those with high marginal propensity to consume (mpc) to those with low mpc, as a result of high anticipated inflation accompanying the devaluation, [3] **de-collateralization** - foreign lenders often require collateral in the form of a domestic non-traded good (e.g land) to limit their loan exposure. An unanticipated devaluation may lower the dollar value of the collateral and generate a credit sqeeze.

rency[19]. For the latter argument, the *"fear of floating"*[20] argument holds sway and the bank will prefer a fixed exchange rate regime over a flexible one[21]. As such, faced with the conflicting features of our EME model, the conventional macroeconomic paradigm will fail to provide a satisfactory answer about the specific form of exchange rate regime.

The two opposing forces embedded in [**4**] provide an interesting and illuminating debate about the choice of the exchange rate regime for an EME. What is the dividing line in this choice ? Where do we draw this line ? If any one particular regime is chosen, what appropriate safeguards must be instilled? Do these safeguards succeed in improving welfare and simultaneously act as potential *bank run prevention devices ?* Since our paradigm is rooted in solid

[19] Even though we do not provide for macroeconomic modelling of speculative pressures and loss of monetary souvereignty, there are dangers that we highlight in this chapter about the possibilities of financial fragility that result from adopting the peg, that could potentially act as a substitute. The dangers in the macroeconomic front, can be subsumed in the "impossible trilemma" doctrine: that it impossible to have a fixed exchange rate regime, perfect capital mobility and an independent monetary policy co-existing simultaneously. For EMEs that still seek on maintaining the peg, there is greater need for sound economic and financial structures capable of withstanding pressures from the defense of the peg.

[20] The "fear of floating" argument lies behind the reasons as to why the officially stated positions of many Central Banks about their exchange rate systems, differ from actual practice.

[21] There is much dispute, in practice, about whether it is the "fear of floating" argument that prompts the adoption of the peg or whether it is the pegged regime that encourages countries to write up debt contracts in foreign currency. The latter perception arises because of the belief that exchange rates will not change, thus lowering risks and eliminating the need to hedge. Thus, in addition to encouraging borrowing in foreign currencies, pegs have discouraged the development of hedging instruments and futures market. This makes the costs of breaking away from the peg even more substantial for the economy as a whole. While it would be wise to limit foreign exchange exposure by regulatory limits of positions, such limits would discourage foreign investors from coming into the country - thus, leading to dis-intermediation. Ize and Powell (2005) identify several problems of multiple equilibria, as the fear of floating argument induces lenders and borrowers to transact in dollars, which, in turn, exacerbates the fear of floating.

microfoundations of financial intermediaries, we contrast the successes of different regime systems that we propose, on their ability to minimise the occurrence of bank runs (where possible) and to help restore the Planner's Second-Best allocation. The shocks to the system depend on the underlying stochastic variables that we study. They may be either information-induced (i.e to the idiosyncratic fundamentals of the bank) or devaluation-induced (i.e to the shadow exchange rate). While a complete comparison of fixed vs flexible regimes on the scale of Mundell-Fleming model, is impossible, our paradigm can help cast light on the debate about design of an appropriate regime. We propose three main regimes, depending on the main aims of the regime:

[**1**] If the aim of the exchange rate regime is to minimise the occurrence of bank runs, we popose a **soft peg with capital controls**. The big question is whether achieving stability in the banking sector will always be optimal or whether the Planner's Second-Best solution will always be achieved ?

[**2**] If the aim is to achieve exchange rate stability, we propose a **managed floating system**. The main conundrum here is that exchange rate stability comes at the cost of destabilising the banking system. Which form of foreign exchange intervention helps minimise the losses in the banking system in welfare theoretic terms ?

[**3**] If the aim is to achieve financial stability (i.e minimise banking and currency crisis), a form of **state-contingent crawling peg system** is our solution.

FIGURE 8.11 : Choice of Exchange Rate Regimes in Practice (i)

Economic Features	Fixed Exchange Rate Regime	Floating Exchange Rate Regime
Lack of credibility in inflation-stabilization ex-ante	✓	
Inability to pre-commit to low inflation rates ex-post		✓ **Note 1**
Increased integration in global financial markets	**Note 2**	✓
Domestic financial sophistication	**Note 3**	✓
Trade as % of GDP (High)	✓**(A)**	
Agricultural exports as % share of trade		✓**(B)**
Manufacturing exports as % share of trade	✓**(C)**	
Monetary Shocks	✓	
Real domestic shocks		✓
External shocks		✓**Note 4**
Liability dollarisation (financial and banking structure)	✓**Note 5**	✓**Note 6**
Flexibility of labour markets	✓	
Fiscal flexibility	✓	

Note 1: Countries that cannot pre-commit to low inflation rates ex-post usually choose some form of compromise between anchor properties of fixed and accommodating properties of flexible regimes. Arrangements that fall into this category include crawling pegs, crawling bands and adjustable pegs.
Note 2: Fixed exchange rate regimes are compatible with increased integration if and only if the domestic banking system is strong enough to resist any interest changes needed to defend the peg.
Note 3: Domestic financial sophistication is taken to mean the existence of a deep and broad market for foreign exchange, the market for foreign exchange derivatives instruments, institutional requirements such as independent central banks and inflation targeting.
Note 4: External shocks include oil price hikes, global interest rate fluctuations, volatility in terms-of-trade
Note 5: Fear-of-Floating argument
Note 6: Floating regimes may have a disciplining influence by limiting the extent of future liability dollarisation.

(A) To economize on transaction costs and minimise exchange rate risks.
(B) Agricultural exports are denominated in foreign currencies (exports volumes are insensitive to fluctuating exchange rates) and subject to volatile terms-of-trade.
(C) Manufacturing exports are denominated in home currencies (exports are thus sensitive to exchange rate changes) and stable terms-of-trade.

Soft Peg with Capital Controls (Stability to Banking Sector)

We studied the implications of the economics of capital controls for our paradigm in the last chapter. We began with the assumption that the exchange rate is a soft peg and that the government is committed to maintain it at this level due to the "fear of floating" argument that results from allowing the currency to float. All foreign depositors were assumed to receive information about their bank's idiosyncratic performance only and not about the shadow exchange rate. We arrived at the result that capital controls can successfully act as *bank-run preventing devices* with a pegged regime but that whether they can replicate the planner's optimal allocation depends on the order in which depositors present themselves to the bank. If all those who are first in the queue are impatient depositors, capital controls prevent runs and achieve an allocation in which impatient depositors receive c_1^* and patient depositors receive c_2^* in period $t = 2$ (banking contractual obligations satisfied). If the sequence order is different (i.e patient depositors get paid first due to them being first in the line of queue), controls on outflows achieve a sub-optimal allocation e.g when $\lambda < 1 - \lambda$, all impatient depositors are forced to consume in period $t = 2$ when consumption is of no avail to them. Thus, a soft peg juxtaposed with a capital control system, can help prevent bank runs but may or may not result in optimal allocation, depending on the order in which depositors present themselves to the bank. We now investigate two extensions for capital controls.

[1] The Special Case of a State-Contingent Capital Control[22]

The above analysis for capital controls draws on the material studied in **chapter 7**. It assumes that the bank does not serve more than λ of depositors who wish to withdraw early when $R \leq R^*$. Let us now assume that the bank

[22] This section contains a variation of an assumption of the main text - I assume that no Sequential Service Constraint (SSC) exists and all depositors who withdraw early decide to share whatever is available equally.

adopts a state-contingent capital control policy such that it promises not to serve more than $\lambda + \lambda_1(R)$ depositors in period $t = 1$. Let $\lambda_1(R) = \frac{\kappa}{\kappa+(1-\kappa)R} - \lambda$, where $\frac{\kappa}{\kappa+(1-\kappa)R} - \lambda$ represents the proportion of patient (foreign) depositors who withdraw early. In this case, when $R \leq R^*$, the bank applies capital controls on outflows, according to rule: $\lambda + \lambda_1(R)$. Thus, in the extreme case in which $R = 0$, all patient depositors withdraw early i.e $\lambda_1(R) = 1 - \lambda$. The capital control rule states that the bank promises to service all depositors who present themselves to the bank. As R rises, the $\frac{\kappa}{\kappa+(1-\kappa)R}$ element decreases - meaning that as R rises, fewer proportion of patient depositors withdraw; thus, the bank promises to service a fixed element λ plus a decreasing element. This state-contingent rule is consistent with the Second-Best allocation of the Planner which we considered earlier.

Corollary 8.2: *Under a state-contingent capital control rule $\lambda + \lambda_1(R)$ and assuming no liquidation of the asset is possible (and no SSC), the resulting allocation of the banking system of the EME replicates the socially-optimal allocation of the Central Bank as a Planner.*

[2] The Special Case of a Chilean-Type of Tax or a Tobin Tax

Experience suggests that, in the 1980s, emerging markets in Latin America (e.g Chile) adopted a tax on capital inflows - this policy was very successful in allowing the country to maintain its crawling peg regime and this policy delivered an economic performance that was better than most of its south American counterparts. The Chilean tax is engineered to influence the distribution of capital inflows more towards the long-term stable elements (e.g Foreign Direct Investment (FDI)) that remain impervious to episodes of economic turmoil, and away from short-term disruptive capital inflows.

A Chilean tax is essentially a tax on short-term capital outflows[23]. The

[23] Unlike the earlier case in which we concentrated in quantitative controls on capital out-

tax works by making it more costly for depositors to withdraw early in crisis-situations. It is a *bank-run preventing device*. To conjecture the application of a Chilean-type of tax in our setup, the tax is designed in such a way that, in tranquil times (i.e when $R > R^*$), it ensures that only impatient depositors withdraw early and all patient depositors withdraw late. In crisis times (i.e $R \leq R^*$), when all depositors present themselves to the bank, the tax makes it less attractive for patient depositors to withdraw early. Thus, overall aim of the chilean tax is to prevent bank runs at the aggregate level, whilst ensuring that, in all states of the world, it is in the interest of impatient depositors to withdraw early and it is in the interest of the patient depositors to withdraw late.

There are, nonetheless, operational problems with a Chilean tax. If the tax levied on short term inflows is excessively high (i.e the net after-tax return to depositors is low), there is distortion of risk-sharing for the sake of preventing bank runs. On the other hand-side, if the government adjusts the before-tax returns to ensure that the after-tax return is unaffected, it means that banks, in their investment allocational functions, must devote more resources to the safe asset and less resources to the risky asset. Lesser investment in the risky asset results in an opportunity cost (due to the fact that it pays off more than the short asset) and results in financial disintermediation.

Corollary 8.3 ***(Optimality of a Chilean-Tax)*** *In addition to being a bank-run preventing device, the appropriate level of a Chilean tax is one that trades-off the risk-sharing and the financial intermediation elements of a bank's activities. More focus on risk-sharing leads to financial disintermediation whilst more focus on financial intermediation leads to distortion of risk-sharing aims. The optimal level of the Chilean tax is one that trades off these two elements.*

flows.

Managed System With Implicit Bank-Run Preventing Devices (Stability to Exchange Rate)

Whilst the choice of a soft peg was an important factor behind many EME crises, some countries (e.g South Africa, Chile and Peru) did remarkably well in averting crises by retaining a floating regime. In the case we are considering (EMEs with liability dollarisation), we have highlighted the dangers with allowing the currency to float. Does managing the exchange rate do a better job by juxtaposing the stability and flexibility features of fixed and floating exchange rate regimes respectively? While a managed float system may help preserve exchange rate stability, our paradigm suggests that there will be a resulting instability in the banking system, depending on the specific forms of foreign exchange intervention.

As highlighted before, managing the exchange rate fluctuations through the use of foreign exchange market intervention, achieves stability of the exchange rate in the short / medium run, at the cost of draining reserves. We studied in the previous chapter that when the international liquidity pool dries up, a currency crisis may follow. In this chapter, we show that if depositors receive a perfect signal of an impending currency devaluation, they may run on their banks (an eventual devaluation-induced bank run occurs at banks). Foreign exchnage intervention brings stability to the exchange rate, at the cost of a possible devaluation-induced bank run in the future.

Managing the exchange rate through interest rate achieves the same goal of bringing stability to the exchange rate but at the cost of greater interest rate fluctuations and banking vulnerability through adverse selection and moral hazard. We studied in the previous chapter that if interest rates affect the bank's risky portfolio performance directly (stochastic idiosyncratic fundamentals), depositors who receive a perfect signal of their bank's idiosyncratic fundamental, may run on their banks. The result is that these fluctuations may induce an information-based bank run. Interest rate management brings stability to the exchange rate, at the cost of a possible information-induced bank run in the economy.

Thus, no matter which specific form intervention in the foreign exchange market takes, managed floats[24] achieve short-term currency stability at the cost of greater short term instability in the banking system (assuming interest rate intervention) or long term instability in the banking system (direct intervention). In the previous chapter, our theoretical setup showed us that a (future) devaluation-induced banking failure leads to higher welfare losses than an information-induced banking failure. What implications does this have for the use of policy instruments designed to stabilise the exchange rate of an EME ?

Corollary 8.4: *An EME (characterised by liability dollarisation) that aims to minimise banking instability and that decides to adopt a managed floating exchange rate system, will prefer to use interest rates rather than foreign exchange reserves, to defend its exchange rate.*

Due to our earlier result (corollary 7.3 and 7.4 of **chapter 7**) that an information-induced bank run is less costly than a (future) devaluation-induced bank run, our model paradigm supports the case for interest rate intervention as mechanism for managing a soft peg for an economy with banking system characterised by liability dollarisation. The growing adoption of managed floating systems and use of interest rate as policy instrument by many EMEs, corroborates our findings.

[24] An alternative to a managed float is to adopt a "crawling band" - Crawling bands have the same problems as soft pegs, especially when the exchange rate hits the lower or upper band. The economies of Mexico (before December 1994), Indonesia (before August 1997) and Russia (before August 1998) were all under crawling band arrangements, prior to experiencing a financial crisis.

State-Contingent Crawling Peg (Stability to Financial System)

If the aim of the regime is to prevent the occurrence of both, a banking and a currency crisis, some state-contingent structure is warranted. While our paradigm remains ambiguous about the specific forms of that state-contingent structure, a few examples can be used to illustrate our point and convey the necessary inuitions.

One particular form that the regime can take is to combine a soft peg with a state-contingent capital control system. We showed earlier that a capital control system can help prevent banking system instability. We also briefly touched the idea of state-contingent capital control earlier and argued that it helps achieve the twinned goals of banking system stability and optimal allocation of resources. This regime helps bring financial stability (i.e prevent both, banking and currency crisis) when shocks affect the idiosyncratic fundamentals of banks. It fails to offer insurance against shocks that affect the shadow exchange rate system.

Earlier, we studied that a managed floating regime achieves the goal of exchange rate stability at the cost of destabilising the banking system, depending on the particular form of intervention. Another regime that can minimise the occurrence of the twin crises, is one that is essentially a managed float but with an embedded state-contingent structure that offsets the main sources of fluctuations that affect the banking system. For instance, if interest rate intervention is proposed to generate exchange rate stability, the resulting impact can be information-induced bank runs through fluctuations in the stochastic fundamentals of the banking system. A managed floating regime that has an embedded structure that can tract these stochastic elements in a way that exactly offsets their impact, will prevent the resulting banking instability and achieve the twinned goals of banking and exchange rate stability. While the idea may seem intuitive, to design such a state-contingent regime is hard since it requires perfect knowledge of the nature of the stochastic fundamentals in the economy.

A natural extension to future research is to develop a formal model that can capture the above intuition. Figure 8.12 (after the conclusion of this chapter) summarises the main characteristics that govern countries adopting particular exchange rate regimes in practice.

8.6 Conclusion

In this chapter, we have attempted to build a completely new theoretical model that outlines the transmission process from a currency crisis to a banking crisis. As in the previous chapter, we use the mechanism design approach to show that the banking allocation is only weakly inferior to the Planner's second-best solution. When no bank runs occur, the banking outcome replicates that of the Planner but under the positive probability of bank runs occurring, the banking allocation is strictly Pareto inferior to that of the Planner. For the banking allocation, consumers are modelled as depositors in a bank characterised by liability dollarisation. We show that when depositors receive some interim precise news about the shadow exchange rate, there is a unique equilibrium in the shadow exchange rate above which depositors withdraw (bank runs occur) and below which depositors stay (no bank runs occur). As such, bank runs are devaluation-induced due to the balance sheet effects. However, under what circumstances will the bank eventually fail ? We motivate the idea of the transmission process as one in which a currency crisis, by itself, causes a bank to fail when no such failure would have occurred otherwise. To this end, we construct a range of simulated values of the bank's idiosyncratic fundamentals and show that, for a positive range only, the bank will be able to ward off such devaluation-induced bank runs.

Whilst considering different orders of causation within a similar economic environment, the last two chapters enable us to throw light about policy implications of our paradigm for Central Banks. Because the material embodied in both chapters deal with an identical banking system, the debate about the main policy implications that draw upon the findings of our work, may interchangeably make use of the rich findings of both chapters. The last chapter, in particular, shows that a funding policy organised by the Central Bank and financed out of foreign reserves, is sub-optimal. We conjecture that, in a multi-period setting with many commerical banks (and assuming zero discounting), the welfare gains from preventing a contemporary information-induced bank run are less than the welfare losses emanating from future devaluation-induced banking crisis. The LOLR story, which is a necessary condition for transmission process, suggests that for an EME characterised by liability dollarisation and foreign capital inflows, the need to coordinate the financial stability role of the Central Bank and the overall macroeconomic objectives of the government (including monetary policy), is of fundamental importance to the Central Bank.

As far as policy recommendations are concerned, the contributions embodied in **chapters 6, 7** and **8** are innovative in two ways. Firstly, they show that the conventional policy measures such as LOLR do have externalities on the rest of the economy, under certain conditions; secondly, they have interesting suggestions for the design of appropriate exchange rate regimes, using a model with solid microfoundations of financial intermediaries. Our approach thus departs radically from the conventional macroeconomic paradigm. Furthermore, the standard macroeconomic paradigm fails to provide a convincing answer as to the exact form of exchange rate regime that must be adopted by an EME characterised by liability dollarisation (argument against floating) and integration in the international capital markets (argument against fixed). These two features of EMEs seem to provide conflicting views on the form of exchange rate regime to be adopted. Our approach enables us bridge that gap and contribute to that debate.

In particular, our approach suggests that, in an emerging market with a banking system characterised by liability dollarisation, the exchange rate regime is one that helps restore the Planner's Second-Best allocation of liquidity and resources (i.e helps avoid the occurence of the twin crises, no matter which flow of causation). If the main aim of the financial system is to keep the exchange rate stable and fixed, using interest rate policy is preferred to using foreign exchange intervention, from a welfare perspective. Both measures result in instability of the banking system. However, interest rate policy only results in information-induced bank runs. Foreign exchange intervention is shown to result in a devaluation-induced bank run. Since infomation-induced bank runs are less costly than devaluation-induced banks runs, we advocate use of interest rate to defend the peg. Conversely, if the aim of the financial system is to preserve banking stability, a soft peg juxtaposed with an appropriate regime of capital controls, will help prevent a bank run. However, whether the Planner's Second-Best outcome is achieved, depends on the order in which depositors present themselves to the bank. Finally, if the aim is to contain the occurrence of both crises (pre-empt the occurrence of a banking and currency crisis), some form of state-contingent structure must be embodied within the exchange rate system so that the Planner's Second Best allocation is achieved. Although we do not model these state-contingent structures formally, we provide some intuition that helps the reader understand their shape and purpose. These measures contain an implanted mechanism that always makes the economy resilient to banking and currency crises and help maintain the Planner's Second-Best solution.

FIGURE 8.12 : Choice of Exchange Rate Regimes in Practice (ii)

General (descriptive) Characteristics of Economies Adopting a Particular Exchange Rate Regime	Exchange-Rate Regime
- Economies that want credibility required in the aftermath of a monetary disorder but that want to retain the flexibility of an 'exit' option in bad times and avoid the straightjacket of lost revenues and lost monetary sovereignty - Economies lack pre-requisites for floating regimes and institutional changes required for successful credible alternative (e.g inflation targeting)	**CURRENCY BOARDS**
- Economies are well integrated with USA; - Economy already uses dollars extensively (liability dollarization is an all encompassing reality); - Economy cannot take advantage of exchange rate as 'exit' option for adjustment to external shocks	**DOLLARIZATION**
- Economy cannot pre-commit to lower inflation rates ex-post	**CRAWLING PEGS**
- Economy wants to maintain credibility advantages of a peg but wants a mechanism that provides adjustment to external shocks - Economy has a diversified trade structure	**BASKET PEGS**
- Economy looks for political and economic advantages involved in harmonising trade and monetary regimes: individual advantage lies in being members of a larger economic space	**MONETARY UNIONS**
- Economy wants to enjoy advantages of monetary independence whilst being integrated in global financial markets. Exchange rate can be used as a response to external shocks Pre-requisites for inflation targeting satisfied: central bank independence, no commitment to alternative targets, reactive monetary policy to exchange rate fluctuations (as long as these influence the target), mechanism for forecasting future inflation levels	**PURE FLOATING REGIMES + INFLATION TARGETING**

Chapter 9

Conclusion and Critical Appraisal

The purpose of this chapter is to provide a nutshell of all the main findings and contributions of the research work embodied in the main chapters of this thesis. It provides a comprehensive overview of our banking environment, the modelling structure adopted and the nature of equilibrium concept that we derive and use throughout the thesis. We contrast our findings with existing work in the literature where necessary and outline the specific contributions we make to the literature.The chapter ends with a brief discussion of the main limitations of our paradigm and suggests avenues for future research direction.

Chapter 1 provides an introduction to the thesis. We begin by identifying two main questions that the thesis intends to solve. These two questions emerged after a comprehensive literature review which allowed us to critically assess the strengths, weaknesses and opportunities in existing research work[1]. We identified a number of gaps in the literature, which we paraphrase in terms of two main questions. The work embedded in this thesis is intended to bridge these gaps and to bring answers to some unanswered questions.

The first question addresses the issue of banking contagion and financial

[1] This literature review forms the basis of **chapter 2**.

crises. There are several major flaws in current theoretical models of banking contagion (Allen and Gale (2000), Dasgupta (2004), Chen (1999), Vaugirard (2004), (2005)) and they can be subsumed as follows:

[1] **(***Conceptual***)** They focus on a narrow concept of *interdependence* to explain contagion. This concept has been proved (on empirical grounds) to be weak through the contributions of Forbes and Rigobon (2002) and of Pesaran and Pick (2007);

[2] (M*ethodological*) Relative to single-bank models, they do not construct new methodological structure to explain equilibrium concept of contagion;

[3] (*Microfoundations*) They do not make the difference between contagion and correlation and do not provide microfoundations for occurrence of contagion;

[4] (*Empirical validity*) They cannot simultaneously explain three stylized facts of empirical banking contagion;

[5] (*Policy-making*) Relative to single-bank models, they do not add to the literature on policy-making, following interventionist policies from Central Banks.

We tried to subsume the above limitations of the literature in the form of the following question: *"How can we develop a model that can endogenously distinguish between banking contagion and correlation in probability terms, given that they co-exist in a given banking panic transmission with two banks that have correlated investments?"* To answer this question, we build a model that offers an explanation of contagion that is different from the concept of interdependence. For this purpose, banks are assumed to have correlated risky investments. We allow for informational spillovers as mechanism that transmits a crisis from bank to bank. Cases involving contagious flow of a crisis across banks will be those associated with the idea of causation, in which the underlying correlation becomes somewhat excessive. Thus, while banks A and B have naturally correlated performances, we are interested in de-lineating that part of performance space in which the failure of bank A has, by itself, caused failure of bank B, when no such effect would have occurred otherwise. Based on the arguments of

Forbes and Rigobon (2002) and Pesaran and Pick (2007), explaining contagion as excessive correlation would yield a more satisfactory concept of contagion. The distinction between contagion and correlation in a banking panic transmission is important because it provides guidance for the Central Bank's regulatory policies. Because of the implicit causation mechanism, contagion warrants microprudential measures. Correlation warrants macroprudential measures.

On the methodological front, we design a dynamic Bayesian game setup for our banks and allow the interractions between private signals of depositors and an endogenous public signal, to guide the occurrence of particular events (contagion or correlation). Because of strategic interractions between depositors across banks, we develop a new methodological structure to solve for equilibrium of the game. The environment in each bank is calibrated to allow for the global games methodology, as way of deriving the probability of events. The dynamic Bayesian approach that underpins strategic interractions across banks, induces us to investigate the specific links between the Perfect Bayesian Equilibrium (PBE) and the trigger equilibrium. On the basis of identifying the trigger equilibrium as a PBE, we explore the results of our findings. We are able to draw the line between contagion and correlation in probability terms and relate the occurrence of each event to some underlying features of the informational attributes of depositors. An improvement over the existing literature that we offer, is the ability to simultaneously explain all three stylized facts of banking contagion . We also provide some fresh insights about the implications of adopting a two-bank dynamic Bayesian environment for the Central Bank's interventionist policies. We address the first question in **chapters 3, 4** and **5**[2].

The second question addresses the issue of banking systems in Emerging Market Economies (EMEs) and international finance. The flaws that we identified in the existing literature, are as follows:

[2] Please refer to Box 1.1 and Box 1.2 of **chapter 1** for an idea as to how these chapters are organised.

[1] Models of bank runs are developed independently of the economic system in which these banks operate;

[2] No theoretical papers in the literature have studied the specificities of EMEs for the operation of banks;

[3] No theoretical papers in the literature have studied the implications of EMEs constraints on the nature of policymaking for banks;

[4] Although the transmission channels between banking and currency crises have been studied on the empirical front (Kaminsky and Reinhart (1999)), there is no theoretical work studying these specific links;

[5] The existing literature on choice of exchange rate regimes is devoid of any microfoundations of financial markets or intermediaries. No contributions in the literature study the choice of monetary regimes on the basis of the ability of regime to bring financial stability.

We tried to subsume the above limitations of the literature in the form of the following question: "*How can we embed a model of banking crisis within an Emerging Market Economy (EME) framework in a way that enables us to study theoretically the transmission mechanism between a banking crisis and a currency crisis ?* " This constitutes the second main question this thesis tries to solve. We first embed a banking model of Allen and Gale (1998) within a Chang and Velasco (2000a) framework. The rationale for using a version of Allen and Gale (1998) is that it contains an implicit mechanism for getting rid of multiplicity of equilibria. The occurrence of banking crises can be endogenised in probability terms. The Chang and Velasco (2000a) environment allows us to use mechanism design approach to solve for optimal allocation of liquidity. In addition, we add two crucial features which provide an innovative touch to our setup: **[1]** a completely liberalised financial system with all depositors being foreign and **[2]** liability dollarisation. The mechanism design approach enables us study some of the allocational features of our banking framework, compared to some theoretical yardstick such as a Planner, and to characterise such allocation on welfare theoretic grounds. From the banking allocation, we are in a position to study the transmission mechanism from a banking crisis to a currency crisis (and vice versa). We derive sufficient conditions explaining the occurrence of such contagious transmissions and offer new insights that have hitherto been unheard of. For instance, lending to a crisis-catalyst bank has often been shown, in the literature, to preserve the assets of the bank and to prevent a crisis. In our setup, such lending may create a channel of crisis of its own on other banks. Our approach also enables us to compare the welfare implications of different policies and to design new structural features in exchange rate regimes so as to minimise financial instability. We address the second main question of our thesis in **chapters 6, 7** and **8**[3]. We now turn to a detailed summary of our approach and findings in each chapter.

Chapter 2 reviews and categorises the literature on micro-systemic risks and on optimal policies designed to mitigate these risks. We propose an analytical taxonomy that studies the existing literature within a well-defined anatomical context. The novelty of this approach is that it helps us identify key areas in the literature in which research work is missing. In fact, we endeavour to provide answers to some of these missing questions in subsequent chapters of this thesis. Thus, apart from being a comprehensive literature review, the material embodied in this chapter helps as a valuable springboard for subsequent chapters. Micro-systemic risks are risks to the financial system that occur when the interaction of a bank with other banks or with financial markets, can propagate an initially localised shock to the whole financial system and can prevent the latter from fulfilling its intermediation and distributional roles. The severe episodes of financial crises that have plagued economies - developed and emerging markets alike - have made more compelling, the need for policymakers such as Central Banks, to develop prudential tools as part of crisis prevention and crisis management policies. We review the success of these policies under different theoretical paradigms.

[3] Please refer to Box 1.1 and Box 1.4 in **chapter 1** for an idea of how these chapters are organised.

We begin our study of the analytical taxonomy of a financial crisis from a *crisis initiation* and from a *crisis propagation* perspective. On the initiation side, we review the literature for single-bank crises. The two major strands in this literature are those that focus on coordination failure problems (*inefficient bank run models* e.g Diamond and Dybvig (1983)) and those that focus on informational asymmetry problems on the asset side (*efficient bank run models* e.g Chari and Jagannathan (1988), Jacklin and Bhattacharya (1988), Allen and Gale (1998)). With new development in economic theory in the 1990s, subsequent research work in the area of banking crises has attempted to model contractual nature of the demand deposit system (Peck and Shell (2003), Green and Lin (2003)) or whereas others have focused on designing ways to get rid of equilibria multiplicity (Goldstein and Pauzner (2005)).

The next part of the chapter focuses on the crisis propagation side. We classify the literature embodied therein in two subsections. The first subsection deals with multiple banks but no financial markets. Here, the nature of the transmission mechanism that connects banks and that transmits a crisis from one bank to the other, is extolled. We review those papers that study financial contagion across banks that are connected by **[1]** balance sheet connections (Rochet and Tirole (1996), Allen and Gale (2000), Dasgupta (2004), Gai and Kapadia (2008)), **[2]** by informational spillovers (Chen (1999), Archarya and Yorulmazer (2008), Vaugirard (2005)), **[3]** by common assets (Cifuentes, Ferrucci and Shin (2005)). In this category, market failures exist on the transmission conduit that connects banks. As a result, any policy attempt designed to mitigate the occurrence of financial contagion, focuses on the design of the network architecture that connects banks. For instance, Allen and Gale (2000) show that, with incomplete network of contracts, a crisis will always spread across the financial system. A complete network, on the other side, has the buffer properties that prevents the trasnmission of a crisis across banks. The second subsection deals with the interractions between banks and financial markets. Financial markets exist to securitize bank assets, to enable banks to sell their assets when they need liquidity or to allow banks to insure against aggregate risks in liquidity. We study how the presence of market failures in the ability of financial markets to fulfill these roles, may deprive homogenous banks of liquidity when they most need it (Allen and Gale (1998), Donaldson (1992)). As a result, financial fragility occurs. If banks are heterogenous (i.e face negatively correlated liquidity shocks), they rely on interbank market for liquidity. Market failures in the interbank market for liquidity, may again lead to financial fragility. A few examples include positively correlated shocks across banks (which renders the interbank market futile) or coordination failure problems and free riding in interbank market. These result in underprovision of liquidity from cash-abundant banks to cash-strapped banks. Models in the second subsection draw on solid microfoundations and they attempt to explain financial fragility from a welfare theoretic perspective. Developing theorems akin to the First and Second theorem of Welfare Economics, Allen and Gale (2004) derive the necessary and sufficient conditions for optimal, incentive-compatible solutions for the financial market's provision of liquidity to banks. They show that, with incomplete demand deposit contracts but complete financial markets, the resulting allocation will always be constrained-efficient. Incomplete financial markets always result in fragility. Thus, from a welfare theoretic perspective, the success of any attempt to introduce policy measures to mitigate financial fragility, depends on the ability of these policy measures to restore the constrained-efficient allocation. **Chapter 2** ends with a brief synopsis of financial accelerator models which stress on how imperfections in financial markets may magnify the swings and intensity of business cycles and have a more entrenched impact on the macroeconomy.

The framework we adopted to classify the existing literature in the first chapter, enables us to appreciate the voluminous amount of existing work and, at the same time, identify those areas of the literature in which existing research work is thin. A virtue of the taxonomy we adopted in the first chapter, is that it enables us to make informed judgements about how to develop models to address those gaps. An important weakness that we identified in existing models of banking contagion, is that the concept of contagion is often inexorably confused with interdependence. In an empirical work on contagion in financial markets, Pesaran and Pick (2007) explained why models of contagion based on the narrow concept of interdependence, may not yield plausible results. Furthermore, existing models that explain contagion across banks from an interdependence perspective, make suggestions for policy implementation that do not differ from those advocated for single-banking crises scenarios. We wanted to develop a microfounded model of banking contagion that addresses this vital element and that offers a completely new perspective on policy proposals for multiple-bank scenarios as opposed to single-bank scenarios. Far from just explaining the transmission of crisis across banks, we wanted to develop a model that could endogenously explain contagion as a case of 'excess correlation' in some states of the world compared to others. At the same time, there are three stylized facts or puzzles in the literature of empirical contagion which we identified: contagion often occurs across unconnected banks or may be clustered across identical banks only or may even be avoided by some banks but not by others. Existing models in the literature cannot provide a simultaneous explanation of all three stylized facts. This provided the drive to build the model embodied in **chapters 3, 4** and **5**.

Another important weakness that we identified, following the taxonomy we developed in the first chapter, is that banking crises models are often written without taking explicit account of the level of development or macroeconomic features of the economy in which they are operating. For instance, an economy with a particular exchange rate regime (which has been adopted for some macroeconomic reason e.g disciplining device for anchoring inflationary expectations), may have structural features that affect the operation of the banking system in its role of liquidity insurance provision. How will the banking system be affected in the presence of these constraints? How different will the nature of a banking crisis be if the exogenous specificity of the macroeconomy is taken into account ? Will a crisis in the banking sector spread to any other sectors ? From a policy perspective, what are the new insights to be provided, that existing models fail to explain ? These temptative questions helped us build the model embodied in **chapters 6, 7** and **8**. We next turn to a summary of our findings in each of the chapters following the first chapter.

Chapters 3, 4 and **5** build on the literature review paradigm of **chapter 2**, by considering a banking panic transmission in a two-bank setting, in which the main propagator of a shock across banks is the informational spillover channel. **Chapter 3**, in particular, introduces the main banking environment of the paradigm to be developed subsequently in the following two chapters. The banking system consists of two Diamond and Dybvig (1983) banks, where banks are modelled as deposit-taking institutions that invest depositors' endowments in an investment technology in return for offering demand deposit contracts that promise to pay depositors when they withdraw according to their liquidity preference. Each bank invests in a risky technology that is perceived to be connected to some unobserved common macroeconomic fundamental. The latter follows a Bernoulli distribution. Depositors of each bank observe a noisy signal of their bank's stochastic idiosyncratic fiundamental. Depositors do not observe the common macroeconomic fundamental that connects the two banks.

The dynamic Bayesian setting that we develop, is a pivotal element of our work and is of essence for subsequent analysis. We assume that depositors of one bank move first to withdraw from their bank after observing their private signal about their bank's idiosyncratic fundamental. In addition, these first-mover depositors also take into accout the prior probability estimates of the common macroeconomic fundamental. The event in the first bank becomes public knowledge. Then, depositors of the second bank make their decision about whether they wish to stay or withdraw from their bank, based on their private signals of their bank's fundamental. In addition to their private signals, these depositors have the informational advantage of observing the event in the first bank. This enables them to reassess their beliefs about the state of the common macroeconomic fundamental, using Bayesian updating mechanics. This art of belief updating constitutes the information externality channel that transmits a crisis from one bank to the other. The novelty of this chapter is manifold. To begin with, we have two banks, instead of one. Furthermore, the Diamond and Dybvig (1983) environment has been richly augmented to take into account two sources of asymmetric information for each bank: noises about the banks' idiosyncratic fundamentals and about the common macroeconomic fundamental. For each bank, in order for the global games approach to work, we construct dominance regions in the fundamental space of each bank and establish the presence of supermodularities (or strategic complementarities) in depositors's payoff structure. Finally, the sequential timing in the behavioural response of depositors allows strategic interraction, both, within and across banks. The dynamic Bayesian setting which we study, provides a perfect recipe for introducing a learning mechanism. The public signal of the event in the first bank allows depositors of the second bank to learn and make stochastic inferences about the common macroeconomic fundamental. This may bias their decision towards staying in their bank or withdrawing. Banks are not engaged in cross-insurance deposits or in interbank loans market. Thus, there is no contractual balance sheet connections across banks. Adopting the global games approach within a dynamic Bayesian environment for multiple banks, in the presence of infomational spillovers and a learning mechanism, is a completely new approach to formalising banking environments and is our major contribution to existing literature on design of banking environments[4].

Chapter 4 deals with the equilibrium characterisation of the sequential move game with incomplete information between depositors of two banks. A legitimate gap in the theoretical literature is that the relationships between dynamic equilibrium concepts such as Perfect Bayesian Equilibrium (PBE) and

[4] Please refer to Box A.3.1 in Section A.3(b) at the beginning of this thesis for an overview of the exact differences between our work and the various papers in the existing literature. Box A.3.1 enables the reader gauge the extent of our exact contribution to knowledge.

the solution concepts of the global games approach, have not received attention. The contribution embodied in this chapter is meant to bridge that lacuna and to establish any such connections. Using the same approach as Carlsson and VanDamme (1993) and Morris and Shin (1998), we begin the chapter by assuming that depositors follow a switching strategy. For the bank whose depositors move first, we show that these depositors play a best response to other depositors of that same bank, given their privately observed signal about their bank's idiosyncratic fundamental and given their prior beliefs about the state of the common macroeconomic fundamental. For those of the second bank, in addition to their private signals about their bank's idiosyncratic fundamental, depositors of the second bank also observe the public signal about the event in the first bank. This causes them to update their beliefs about the state of the common macroeconomic fundamental and to take these posterior beliefs into account when making their decision to stay or withdraw. We show that depositors of the second bank play a best response to other depositors of that same bank, given their private signals and given their posterior beliefs about the state of the common macroeconomic fundamental (after observing the event in the first bank). We next characterise the PBE of the game and derive the best response correspondences for each depositor of either bank. The main lesson of **chapter 4** (which has, hitherto, not been established in the literature) is that this PBE can be represented as trigger equilibrium in depositors' strategy. The trigger equilibrium in each bank's idiosyncratic space, is one above which all depositors stay (bank succeeds) and below which they all withdraw (bank fails). Given the existence of dominance regions in each bank and the presence of supermodularities in depositors' payoff structure, we show that such a trigger equilibrium actually exists for each bank, using the global games approach of Morris and Shin (1998). This innovative result enables us focus on trigger equilibrium concept throughout the rest of the analysis. A legitimate advantage of working with a trigger equilibrium is that it helps characterise the probability of events in the idiosyncratic fundamental space. A few other properties of the trigger equilibrium are also considered.

Chapter 5 deals with the specific mechanics of the belief updating process for depositors of the second bank and moves on to deal with the main conclusions and findings of the paradigm developed in the last couple of chapters. We provide statistical structure to the beliefs adjustment process and show that, if the public information about the event in the first bank, is used for Bayesian inference about the state of the common macroeconomic fundamental by depositors of the second bank, then, in the equilibrium profile of the game, contagion and correlation both occur with positive probability, with contagion modelled as a state-contingent change in the cross-bank correlation. Since the two banks are naturally correlated in all states of the world, we show that contagion is a special case in which this correlation becomes excessive. It is also a state which is characterised by causation i.e the failure of one bank causes depositors of other banks to withdraw from their bank. This microfounded approach to modelling contagion as excess correlation is appealing since it represents a radical departure to the narrower version of interdependence, currently described in the literature (Allen and Gale (2000), Dasgupta (2004)). Our result is thus a theoretical adaptation of the empirical work of Pesaran and Pick (2007). The endogenous characterisation of probabilistic assessments of contagion and correlation, enables us distil between these two concepts as equilibrium phenomena and to assess their relative importance in a given banking panic transmission setting.

One of the innovative results of **chapter 5** is to characterise the relative importance of contagion and correlation as a function of informational attributes of depositors. Prominent papers in the literature that attempt to show how the nature of equilibrium varies with informational structure include Hellwig (2002), Angeletos, Hellwig and Pavan (2006), (2007). Our modelling structure differs fundamentally from these papers in that Hellwig (2002) deals a stylized static coordination game with incomplete information whereas Angeletos et al (2006), (2007) deal with the dynamic equivalent. Our approach is entirely adaptable to the banking world and has been calibrated to take into account the specificities of deposit-taking institutions. Furthermore, in Hellwig (2002), Angeletos et al (2006), (2007), the private and public signals are on the same variable. In our setting, the private and public information reflect inferences about different economic variables[5]. We coin the new concept of 'informational dominance' and show that contagion is characterised by public informational dominance in depositors' information set. Thus, we assert that a robust model of banking contagion that relies on the informational channel, will explain the phenomenon of banking contagion when depositors in other banks give relatively more importance to the publicly observed event about the first bank than to their private information about their own bank. While this result may seem similar to the herding stories of Banerjee (2002), an important difference is that there is no pause in information aggregation in our setup. Furthermore, for contagion to occur, depositors in the second bank do not ignore their private signals. They simply give relatively more importance to the public signal reflecting the event in the first bank than to their private signals.

A number of applications to real world issues are considered. We identify several stylized facts in the literature of banking contagion - which existing models that focus on the narrower version interdependence, cannot satisfy - and we show that our approach can simultaneously satisfy all three stylized facts or puzzles : in particular, contagion may exist among banks that are not directly connected (*zero-link puzzle*); contagion may cluster among identical banks only or banks that have similar investments and liability structures (*clustering puzzle*); among identical banks, some can avoid a contagious crisis whereas others cannot (*avoidance puzzle*). We can explain the first puzzle through the presence of informational spillovers. The second puzzle can be explained through commonality of investments and exposure to the same macroeconomic fundamental. The last puzzle can be explained by the presence of extra strong idiosyncratic

[5] The private information of depositors is on the bank's idiosyncratic fundamental whereas the public information is on strategic inferences made on the common macroeconomic fundamental, as a result of depositors of the second bank observing the event in the first bank.

fundamentals, which lead to depositors attaching relatively more importance to their private signals than to the public signal of the event in the first bank (private informational dominance).

On the policy side, being able to distinguish betwen contagion and correlation is important since both events warrant different policy actions. Correlation requires macroprudential regulation or macroprudential policy measures. Contagion necessitates the use of microprudential policy measures. Thus, in policy implementation circles, our setup enables us draw the line between micro and macroprudential measures. A few contributions to the literature of microprudential policy measures are also mentioned. In particular, our emphasis on the concept of intertemporal banking substitution following policy externalities when intervening at a crisis-catalyst bank, can help add a new dimension to the way policymakers, like Central Banks, go about implementing policy. The policy proposals currently implied by multi-bank models such as Allen and Gale (2000), Dasgupta (2004), Chen (1999), Vaugirard (2005), are not different to those implied by single-bank models such as Diamond and Dybvig (1983) since they explain contagion from the existence of direct connections (i.e interdependence). Our framework for policy implementation is a contribution since, to our knowledge, there are no other multi-bank papers in the literature that show the dynamics of informational attributes on policy design and implementation.

Chapters 6, 7 and **8** consider the special case of banking systems in Emerging Market Economies (EMEs). Banking models in the literature are developed, regardless of the nature of the economy in which they operate. EMEs, for instance, are characterised by a number of stylized facts that are not applicable to rich / developed economies and that make the analysis of traditional banking models futile. **Chapter 6** provides an analytical afterthought of a banking crisis model applied to an EME. Our aim is to appreciate how the complexities and subtleties of an EME may interact with traditional features of banking crises models and have implications for policy that would not otherwise be applicable to developed economies. We are interested in studying how different the nature of banking crises will be when these features of an EME are duly taken into account. We begin by constructing a small open EME with a liberalised domestic financial system which allows foreign money to be intermediated through its bank. The banking system is characterised by the existence of Allen and Gale (1998) banks. Unlike Allen and Gale (1998), all depositors are assumed to be foreign investors. Each bank accepts deposits in a foreign currency (dollar) and invests the resulting proceedings in a non-tradable asset denominated in a domestic currency (peso). Banks obtain pesos by exchanging their dollar deposits at the Central Bank for pesos. Thus, while the balance sheet of each bank is characterised by standard asset-liability maturity mismatch, the innovative approach of this framework, compared to banking models in the literature, is that it is also characterised by unhedged asset-liability currency mismatch.

The purpose of **Chapters 7** and **8** is to analyse how a banking crisis may contagiously lead to a currency crisis and vice versa. Using the mechanism design approach[6], **chapter 7** characterises the socially optimal outcome that is obtained in our model if the Central Bank is assumed to be a Planner who allocates resources across time and states of nature. An important contribution that we make is that we show that the existence of a pecking order in the implementation of optimal allocation of resources and liquidity, under different classes of mechanisms. If the Planner observes the stochastic fundamentals of the economy, the Revelation Principle shows that, by offering direct incentive-compatible mechanisms, the resulting allocation implements the first-best solution. The term structure of demand deposit payment to depositors is non-contingent in that the Planner succeeds in providing insurance against liquidity risks and aggregate risks. If we make the more realistic assumption of the Planner being unable to observe the stochastic fundamentals, the best that the Planner can do is to offer an approximate truthtelling mechanism. The allocation is second-best and the term structure of payments to depositors is

[6] The Central Bank, commercial banks and foreign exchange market are all considered to be part of the mechanism implementation.

state-contingent. Here the Planner can only offer insurance against liquidity risks but not against aggregate risks. These mechanisms depicting the case of the Central Bank as social Planner, represent a special case but they are essentially used as theoretical yardstick against which we compare the banking outcome. We show that the mechanism offered by a decentralised banking allocation, is weakly Pareto inferior to the allocation of the Planner under the second-best outcome. With a decentralised banking system, we show the existence of a unique threshold in the bank's fundamental space, which characterises the probability of events (banking crisis or no banking crisis) in the bank. This result departs radically from that of Chang and Velasco (2000a) who show multiplicity of equilibria in an open economy context. When no banking crisis occurs, the banking allocation replicates that of the Planner. When a banking crisis occurs, the allocation is strictly Pareto inferior. The success of any policy designed to ward off a banking failure, can thus be measured on the ability of that policy to restore the second-best allocation of the Planner.

The banking outcome in **chapter 7**, is a decentralised case in which depositors receive some precise information about their bank's idiosyncratic fundamental at some interim stage. We characterise the existence of a unique dominant equilibrium in depositors' strategy, above which it is dominant for depositors to stay (no information-induced bank run occurs) and below which it is dominant for depositors to withdraw (information-induced bank run occurs). The outcome with no bank runs offers insurance against idiosyncratic risks only but not against aggregate risks. This outcome coincides with the Planner's second-best solution. However, the case in which a bank run occurs, is strictly Pareto-dominated by the second best outcome of the Central Bank as the social Planner. Thus, overall, the banking outcome is weakly dominated by the Second-Best solution of the Planner. We then move on to explore the mechanism that contagiously transmits a banking crisis to a currency crisis. To begin with, we assume that the exchange rate regime is a soft peg. A notable contribution that we make is to provide theoretical justification for Lender-of-

Last-Resort (LOLR) in an EME context. Unlike standard bank run models that provide the economic rationale for LOLR by showing the ability of LOLR to help preserve the bank's assets, we show that in an EME, LOLR may sometimes be sub-optimal even if it manages to preserve the asset of the bank experiencing liquidity problems. In particular, we show that under certain parametric restrictions, LOLR may contagiously transmit a crisis from the banking sector to the foreign exchange sector. Thus, it may be sub-optimal for the Central Bank to use its reserves for the twinned task of defending a peg and for bailing out illiquid banks ex-post. An interesting conjecture of our paradigm is that, in a multi-period setting with many identical banks, interventionist policy measures engineered by the Central Bank (e.g LOLR)) may be inefficient due to intertemporal substitution of banking crisis in the economy. We consider the effectiveness of various safeguard strategies (e.g capital controls) in improving the resilience of banking systems of emerging markets, by studying their ability to restore the Planner's Second-Best solution. A number of conjectural applications are considered as extensions of the main model predictions.

Chapter 8 adopts a structural design feature that is similar to that of **chapter 7** and deals with the case of reverse causation from currency crisis to banking crisis. We assume that depositors receive some interim precise information about the 'shadow exchange rate'. We characterise the existence of a unique equilibrium above which depositors withdraw (devaluation-induced bank run occurs) and below which depositors stay (no devaluation-induced bank run occurs). In particular, we show that a devaluation-induced banking crisis may, through balance sheet effects, lead to bank insolvency for a simulated range of its idiosyncratic fundamental values only. Some implications of our financial paradigm for the government's fiscal policy stance and for the design of exchange rate regime, are also conjectured.

The last parts of **chapters 7** and **8** study the design of prudential policy options for EME. We come with certain proposals that have so far not been identified in the literature but, which we believe, are crucial given the findings of our framework. One of the appealing features of our paradigm is that it is offers a framework that is deeply rooted in microfoundations of financial intermediaries and in the economic realities of an EME, to study macroeconomic issues. As a result, our approach can contribute in a novel way to the debate on the design and choice of exchange rate regimes in EMEs, based on the ability of the system to minimise the likelihood of banking and currency crises (twin crises) occurring. As mentioned in the introduction, this departs radically from the current macroeconomic paradigm that tends to focus on credibility issues and on ability to control inflation, as the overriding factor influencing the choice of exchange rate regimes.

The main implications for policy that we offer, depends on the aims and objectives of the policymaker. A notable virtue of our approach is that we can use our microfounded model of financial intermediation in EMEs, to offer fresh insights on the use of policy instruments and on the design of exchange rate regime. If the aim of the policymaker is to keep the exchange rate stable, it may do so by either using interest rate policy or by using foreign exchange intervention policy. Current macroeconomic models fail to identify the effectiveness of these policy instruments in welfare terms. This is where our contribution becomes important. In this respect, the LOLR story that we develop in **chapter 7**, and that is entirely new to the literature, has potent welfare implications for the choice of policy instrument that the Central Bank has to use, in its defense of the peg. Interest rate policy may invite information-induced bank runs due to induced stochastic changes in the value of banks' assets. Foreign exchange intervention may result in devaluation-induced bank run due to its effect on the international liquidity position of the economy. Thus, an important contribution that we make is that attempts to bring stability to the exchange rate in an EME, may inevitably result in underlying instability in the banking system. Because a devaluation-induced banking crisis results in a greater welfare loss than information-induced banking failures, our paradigm in both chapters, conjectures that using interest rates to defend the peg may be less costly than using foreign exchange intervention. The burden of higher interest rates in the form of stochastic variations in the bank's risky asset returns (induced, say, by adverse selection and moral hazard), may be less than the burden of increased currency pressure induced by draining foreign exchange reserves as a result of intervention. Conversely, if the aim of the policymaker is to pre-empt the occurrence of both crises (i.e eliminate the likelihood of both crises), some state-contingent structure in the exchange rate regime is important. The aim of the state-contingent structure is to enable restore the Planner's second-best allocation. A few propositions are studied e.g crawling peg systems, capital controls, managed floating regime.

In the last part of this extended conclusion, we highlight some of the weaknesses of our paradigm and suggest some avenues that may prove helpful for future research work. For **chapters 6, 7** and **8**, an interesting development will be to extend our model to include multiple banks and allow for multiple periods and include moral hazard. This approach will enable us formalise the main conjectures we have developed. The formal development of the notion of intertemporal substitution of banking crisis, seems promising since it has, hitherto, been unheard of, in the existing literature. In particular, it contains theoretical justification that LOLR may not always be benign in an open economy. Furthermore, an interesting follow-up is the formalisation of state-contingent structures in exchange rate regimes. In the main parts of the text, we provided simple intuitive arguments depicting how such structures will operate. To develop a theoretical model that embed these structures and that show how they can help thwart the occurrence of the 'twin crises' and achieve the Planner's Second-Best solution, seems to be a prominent way forward.

One of the virtues of doing research in the fascinating area of financial crises is that it is a topic that never becomes obsolete. Each decade has seen the emergence of a new form of financial crisis with new stylized facts. In the 1980s, for instance, financial crises were mostly of developmental nature, especially with the debt crisis problems, the hyperinflation of 1980s and the currency crises of

1970s that led to the development of the first generation model of currency crises. The early 1990s witnessed a few form of currency crisis that did not have its roots in woeful government economic mismanagement but rather, with self-fulfilling beliefs and expectations of the financial markets. The late 1990s witnessed the East Asian debacle, with the East Asian economies, once paraded as the paragons of economic virtue, teetering on the brink of economic disaster. The East Asian turmoil brought new challenges to the front of economic scrutiny: there was now, a growing awareness of the role of banks in financial crises, the speed with which a crisis can spread contagiously across countries, difficulties with Moral Hazard and crony capitalism.

At the time of writing up this thesis, the world economy was sinking into generalised global depression that has been unseen since the time of the Great Depression of 1930s due to the credit crunch crisis of 2007-2008. Even though the credit crunch crisis has vindicated the role that banks play in modern financial crises – an aspect which has become the norm since the East Asian turmoil – there are now new elements that have come into the limelight: banks are seen as having common exposure to certain high risk sectors such as real estate and the interaction between banks and financial markets has encouraged risk-taking behaviour by banks in a way that is not readily understandable by agents in the financial markets.

One of the most interesting facts about financial crises is that they always change in nature, speed and intensity each decade. However, while this attribute represents an opportunity to potential researchers to showcase their academic prowess, it makes papers based on the old vintage financial crises rapidly obsolete. Fortunately, our main theoretical paradigm (embodied in **chapters 3, 4** and **5**) has escaped this ill-fated scenario (even without us knowing it). Our theoretical paradigm was developed to have bite on the East Asian turmoil of 1997. However, aside of the fact that we have developed a theoretical model of financial contagion that offers a different look at financial contagion as a concept, our model results are robust in that we provide theoretical justification of contagion as a function of informational attributes of agents in the economy. For instance, we do purport, through the concept of intertemporal substitution of banking crises, that policy measures administered at one bank may have externalities on the behaviour of agents of other banks in the economy and may, by itself, create a channel of contagion of its own. This phenomenon was concurred by Shin (2009) in his observation of the Northern Rock crisis of 2007 in the UK. The Northern Rock crisis of 2007 erupted when depositors of the bank decided to run on the bank, following fears of problems about the bank's liquidity position after the Bank of England intervened to assist the bank financially. This fact confirms the belief that depositors are wary and sensitive of public news relating to their banks and that they do act in response.

While the reader appreciates that the main purpose of building the paradigm in **chapters 3, 4,** and **5**, was theoretical, an interesting follow-up of our paradigm would be to test the model empirically. However, in so-doing, we would face a number of ostensible constraints. We identify three constraints in our route towards empirical modelling:

[1] A natural constraint we face is the fact that most banking systems of the world have explicit deposit insurance schemes that partially covers depositors' exposures to potential bank runs. Our paradigm does not assume the existence of such insurance. Thus, the theoretical gravity of banking contagion problem in our paradigm, may be somewhat over-exaggerated.

[2] A second potential problems is about datasets that actually identify episodes of multiple bank collapse in a banking system. Due to the prompt intervention of Central Banks around the world to bailout commercial banks in trouble, it becomes hard to identify an episode of banking failures arising essentially from a bank run perspective. Central Bank intervention is mostly designed to inject liquidity into banks, restructure their balance sheets, and recapitalise them (where necessary) in order to deal with liquidity and solvency problems. As such, if a multiple banking collapse happens (if at all), it is usually ephemeral in nature.

[3] A third constraint is the fact that our model is micro-founded in nature. It thus becomes a problem to model key micro-theoretical variables in practice. Key issues such as coordination failure, private information, public news etc become difficult to be constructed and identified without the development of indices that, per se, may attract significant controversies among empirical economists and practitioners. In Box 9.1 (please turn next page), we endeavour to provide a follow-up to our theoretical work by suggesting a practical way of implementing and testing our model. However, due to the pertinent problems that we have identified as aforementioned, the six-stepped approach can only be applied to countries (rather than banks) experiencing financial crises transmissions. In order to follow down that route, we would need to re-calibrate our model specificity to account for country (rather than bank) subtleties. We conjecture that transforming our analysis from one that involves banks to one that involves countries, will not change the main theoretical predictions of our paradigm.

An alternative extension to our approach – one that will adapt our model predictions to the credit crunch crisis of 2007-2008 - would be to analyse the informational spillover channel in a context of commercial bank interactions with financial markets. As mentioned in **chapter 1**, banks can use financial markets to issue claims against their long assets (i.e engage in securitization). Developing a multi-bank framework with a financial market and moral hazard, seems to be a prominent theoretical way forward in order to take our approach to the next step.

BOX 9.1: A Quick Analytical Afterthought About Implementing Our Paradigm of **Chapters 3, 4** and **5** in Practice

[1] Identify banks that have common exposure to some macroeconomic fundamental (e.g exchange rate movements for banks engaged in *'liability dollarisation'*);

[2] Identify all past episodes of movements in the macroeconomic fundamental and the performance of banks during these episodes (e.g correlated failures). Identify those episodes of excessive correlation;

[3] Control for the common macroeconomic variable during these episodes and perform simulation exercises as to whether these bank failures would have existed;

[4] Banks may, in this case, fail because depositors have altered their behaviour based on failure of some banks (contagion) or because of some 'external' random factors;

[5] Construct an index of the *'Relative Importance of Public News'*;

[6] Identify from simulation experiment, to what extent the 'excess correlation'(identified in [3]), can be attributed to this *'Relative Importance of Public News'*. This excess would constitute Contagion in our setup.

Main Caveat – How to construct the *'Relative Importance of Public News'* index in practice ?

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Note: All references from the Bank of England's Financial Stability Report (FSR) have been included as footnotes in the main text.

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Appendix

A.1 Additional Notes for Chapter 3

A. The Diamond and Dybvig (1983) model was instrumental in concocting a microtheoretic account of bank balance sheets by allowing for *liquidity preference shocks* modelled as uncertainty about the timing of consumption preferences, *asset-liability maturity mismatch* and *inverse relationship between liquidity and profitability.* Banks are highly leveraged institutions that act as a mechanism that provide insurance against liquidity preference shocks. By pooling the endowments of the investor, they offer demand deposit contracts that make promises of consumption contingent on the date of withdrawal of the investor. The latter achieves better combination of liquidity services and returns on investment than alternative mechanisms such as financial markets. A natural result of a bank engaged in such maturity and liquidity transformation activity is that it must have a balance sheet that makes it prone to various risks.

B. The optimal level of bank regulation is subject to debate. A new field in microeconomic theory of banks is that banking panics are viewed as a natural consequence of a banking system fulfilling its allocational roles as highlighted by the Diamond and Dybvig (1983) environment, highlighted in A above. Thus, any attempt to deal with banking crises ex-ante through the adoption of appropriate regulatory guidelines, will inevitably impinge on the ability of the banking system to perform its roles efficiently. Whether banking regulation is desirable or not, crucially depends on the benefits of such regulation exceeding the cost of so-doing. These models trade-off the ex-post benefits of avoiding bank failures with the ex-ante drawbacks of impinging on the bank's ability to fulfill its allocational roles.

C. The concept of **financial contagion** described here is a restricted version of an all embracing general term: that of '**systemic risk**'. With financial contagion, we are concerned with a case involving multiple banks and there is no interaction of banks with financial markets. One concept of *systemic risk* allows for the interaction between a bank and a financial market in an incomplete market setup, and which leads to excess price volatility for the asset that the bank holds. Excessive (endogenous) asset price volatility may prevent banks from getting liquidity when they need it the most and may mean that the bank is unable to meet its contractual arrangements to pay depositors and eventually fails. Systemic risks may alternatively refer to the transmission of a crisis from bank to bank (with transmission mechanism broadly defined) so that there is an overall financial meltdown. See Chapter 2 for more details.

D. Brief expose of Real Contagion Models: See Chapter 2 for more details

E. Brief expose of Pure Contagion Models: See Chapter 2 for more details

F. Differences between Interdependence and Contagion

Interdependence

- channel of banking panic transmission (same with crisis as without crisis)
- cross-bank linkages before a financial crisis (same after a crisis)

Contagion

- new channel of banking panic transmission emerges (conditional on event observed in first bank)
- cross-bank linkages after a crisis differ from those before
- represented by an endogenous change in correlation / co-movements of events across banks, conditional on the event in first bank

F.1 This lack of predictability as to which banking equilibrium will prevail makes it difficult to study how a bank failure may spread from one bank to another. Put differently, if a model can predict that, depending on depositors' beliefs formation, any outcome of Bank A can be an equilibrium but it remains silent about beliefs, it is hardly able to predict how the outcome of bank A can affect Bank B. Similar problems arise in any international financial crisis model with a strong element of self-fulfilling beliefs. The existence of multiple equilibria makes it very difficult to examine individual bank runs, which compounds the difficulty involved in isolating contagious effects in a multi-bank setting. Quoting from Vaugirard (2005), "*....indeed the key sticking point when trying to display pure contagion in models of financial crises with multiple equilibria and based solely on self-fulfilling beliefs, is that the mechanism for jumps between equilibria, is not articulated. Therefore, these models fail to rigorously capture contagious effect in which a crisis in one country (i.e the particular outcome among the set of possible equilibria) affects the likelihood of a crisis in another country....*" There are two theoretical ways out of the conundrum: (a) identify a particular channel pinning down the cause-effect relationship out of the whole set of possible multiple outcomes; (b) use global games methodology pioneered by Carlsson and VanDamme (1993) and reformulated by Morris and Shin (1998) in a model of speculative currency attack to identify the existence of an equilibrium.

G. Theoretically, this discontinuity in the international transmission mechanism may be caused by panics, asymmetric information or learning. We subsume the notion in the concept of 'change in behaviour' of investors. The notion of contagion as a state-contingent change in correlation, has implications for diversification benefits of investors. Leaving aside the banking world and focusing on financial markets only, contagion would be viewed, from that perspective, as a situation of "excessive" asset price correlation during crisis times as opposed to tranquil times. As the argument goes, this means that diversification may fail to deliver exactly when its benefits are needed the most.

H. Brief expose of Dominance Regions

(**Strict Lower Dominance Region (SLDR)**)[1] **(**Fundamental-Based Bank

[1] $\{\theta_i : \min\{\ [\theta_i < u^G],\ [\theta_i < u^{Bad}]\}\} \equiv \{\theta_i : [0 \leq \theta_i < u^G]\}$

Failure) $\left\{\theta_i : [0 \leq \theta_i \leq u^G]\right\} \Rightarrow$ Region of the $\theta_i - space$, for which bank i fails with probability 1, no matter what the state of the common macroeconomic fundamental is. Associated with the idiosyncratic fundamental being "Too Low To Succeed".

(Weak Lower Dominance Region (WLDR)) $\left\{\theta_i : u^G < \theta_i < u^{Bad}] \right\} \Rightarrow$ Region of the θ_i-space for which bank i fails irrespective of the behaviour of its patient depositors if and only if the common fundamental is in its bad state.

(**Strict Upper Dominance Region (SUDR)**)[2] (Fundamental-Based Bank Success) $\left\{\theta_i : [\theta_i \geq u^{Bad} + z]\right\} \Rightarrow$ Region of the $\theta_i - space$, for which bank i succeeds with probability 1, no matter what the state of the common macroeconomic fundamental is. Associated with the idiosyncratic fundamental being "Too Large To Fail".

(**Weak Upper Dominance Region (WUDR)**) $\left\{\theta_i :\ u^G + z < \theta_i \leq u^{Bad} + z]\right\} \Rightarrow$ Region of the θ_i-space for which bank i succeeds irrespective of the behaviour of its patient depositors if and only if the common fundamental is in its good state.

All four segments put powerful assumptions on the role of θ_i as a driver of bank i's performance. The only difference lies in the interpretation. For SLDR and SUDR, the precise state that the common macroeconomic variable takes, does not matter. For SLDR (respectively SUDR), θ_i is so low (respectively high) that the bank is guaranteed to fail (respectively to succeed). On the other hand side, with WLDR and WUDR, the state of the common fundamental does matter. For example, suppose that the state of the common fundamental is bad. For bank i, any θ_i lying between u^G and u^{Bad} would be classified as part of the 'lower dominance region'. If the state of the fundamental was good, θ_i lying in the $\left[u^G, u^{Bad}\right]$ interval would be part of the segment of θ_i , for which the bank's behaviour would depend on the behaviour of patient depositors. A similar analysis can explain the rationale for WUDR and SUDR.

[2] $\left\{\theta_i : \max\left\{[\theta_i > u^G + z],\, [\theta_i > u^{Bad} + z]\right\}\right\} \equiv \left\{\theta_i : [\theta_i > u^{Bad} + z]\right\}$

A.2 Appendix for Chapter 3

PROOF OF REMARKS 3.1 AND 3.2

Remark 3.1: (**No-Dominance signal segment**) *Attention will be restricted to the segment of the signal space in which there is strategic interraction (i.e Dominance is ruled out). This means that* s *lies in interval* $[s_L,\ s_U]$, *where* $s_L \equiv u^G - \varepsilon$ *and* $s_U \equiv u^{Bad} + z + \varepsilon$.

Remark 3.2: (**Uniformity of Prior and Posterior distribution**) *While the prior distribution of the idiosyncratic fundamental is common knowledge and follows the uniform distribution law, the posterior distribution of the idiosyncratic fundamental, through specific restrictions on the degree of precision of the signals, will also follow the uniform distribution law. The necessary and sufficient condition for that restriction on the noise structure is:* $2\varepsilon < u^G$.

Proof: While the prior distribution of the idiosyncratic fundamental is uniform, it only suffices to impose sufficient structure on the noise technology in order to be assured of uniformity in posterior estimates of the idiosyncratic fundamental. We know that the error technology is uniformly distributed on $[-\varepsilon, +\varepsilon]$, with density rate $\frac{1}{2\varepsilon}$ and that the prior distribution of the idiosyncratic fundamental is uniform on $[0,1]$. In order to guarantee that the posterior distribution of θ_i, conditional on observing the private signal s, is uniform, we need to ensure that the support of θ_i, conditional on s, namely $[s-\varepsilon,\ s+\varepsilon]$, lies exactly within the range that allows for strategic interraction among depositors i.e $[0,1]$.

[1] We require that $\min\left[s-\varepsilon,\ s+\varepsilon\right] > 0$. Restriction $\left[u^G - \varepsilon\right] > 0$ implies that $\varepsilon < u^G$. Furthermore, the assumption that $s > s_L$ is implied by setting $s > \inf\{s : \Pr ob(\theta < \theta_L \mid s) < 1\}$. Thus, we are left with a restriction that $\varepsilon < s$. However, to allow for strategic interraction, $s > u^G - \varepsilon$. The fact that $\varepsilon < s \Rightarrow \varepsilon < u^G - \varepsilon$. Thus, $2\varepsilon < u^G$.

[2] We require that $\max\left[s-\varepsilon,\ s+\varepsilon\right] < 1$. This implies $s+\varepsilon < 1 \Rightarrow \varepsilon < 1-s$. With Restriction $\left[u^{Bad} + z + \varepsilon\right] < 1$, the assumption that $s < s_U$ (to rule out

dominance as per remark 6), implies that $s < u^{Bad} + z + \varepsilon$. Since $\varepsilon < 1 - s$, we can rewrite the whole expression as $\varepsilon < 1 - \left(u^{Bad} + z + \varepsilon\right) \Rightarrow 2\varepsilon < 1 - u^{Bad} - z$.

Thus, restriction $\left[u^{G} - \varepsilon\right] > 0$ and restriction $\left[u^{Bad} + z + \varepsilon\right] < 1$ imply that $2\varepsilon < \min[u^{G}, 1 - u^{Bad} - z]$. By assumptions $[a.1]$, $[a.2]$ and $[a.3]$ in chapter 2 , we know that $0 < u^{G} < u^{Bad} + z < 1$, implying that $u^{G} < 1 - u^{Bad} - z$. Thus, restriction $2\varepsilon < u^{G}$ is a necessary and sufficient condition for the uniform law to be applicable to posterior distribution

A.3 Appendix for Chapter 4

PROOF OF PROPOSITION 4.1

Proposition 4.1: *If the event in Bank A is used for Bayesian updating only, then the Perfect Bayesian Equilibrium of the dynamic game between $\Gamma_{A,t=1}$ and $\Gamma_{B,t=1}$ can be represented as a trigger equilibrium.*

Proof: (use of Intermediate Value Theorem)

Let assessments $\{\, \sigma(\Theta^{A}_{t=1}), \sigma(\Theta^{B}_{t=1})\}$ and $\{\, \zeta, \zeta\prime\}$ denote the Perfect Bayesian Equilibrium of the game between $\Gamma_{A,t=1}$ and $\Gamma_{B,t=1}$. Any depositor in $\Gamma_{t=1}$, will play a best-response to actions of predecessors and successors (where applicable), with the best response function defined by $\Psi^{A}(.) = \max[2P - 1]\int_{s^*}^{s^*+\varepsilon} \pi(\theta, \delta(s^*, \theta))\mu(u \mid \Theta^{A}_{t=1})d\theta$ and $\Psi^{B}(.) = \max[2P - 1]\int_{s^*}^{s^*+\varepsilon} \pi(\theta, \delta(s^*, \theta))\mu(u \mid \Theta^{B}_{t=1})d\theta$, depending on whether he plays in $\Gamma_{A,t=1}$ or in $\Gamma_{B,t=1}$.

For a depositor in $\Gamma_{A,t=1}$, the expected utility, $EU[s^*, \zeta] = [2P - 1]\int_{s^*}^{s^*+\varepsilon} \pi(\theta, \delta(s^*, \theta))d\theta$,varies continuously with s^*. High values of θ are associated with low value of proportion of early withdrawals, $\delta(s^*, \theta)$. Thus, net payoff to staying, $\pi(\theta, \delta(s^*, \theta)$ is high and greater probability is attached to staying in the $EU[s^*, \zeta] = P\int_{s^*}^{s^*+\varepsilon} \pi(\theta, \delta(s^*, \theta))d\theta + (1 - P)\int_{s^*-\varepsilon}^{s^*} \pi(\theta, \delta(s^*, \theta))d\theta$ expression elaborated in the main text of chapter 3, where $\int_{s^*}^{s^*+\varepsilon} \pi(\theta, \delta(s^*, \theta))d\theta > 0$ and $\int_{s^*-\varepsilon}^{s^*} \pi(\theta, \delta(s^*, \theta))d\theta < 0$. For low realisations of θ, we have a reverse ordering: $\delta(s^*, \theta)$ is high and

$\pi(\theta, \delta(s^*, \theta)$ takes a low (negative) value and greater probability is attached to the negative element of $EU[s^*, \zeta]$. Thus, generalising the argument to any depositor (no matter to which game he belongs to), we can argue that he will stay if $EU[s^*, \zeta] > 0$ and will withdraw if $EU[s^*, \zeta] \leq 0$. Since $EU[s^*, \zeta]$ is continuous and monotonically increasing in s^*, then by the intermediate value theorem, $\exists\ s^*$ such that $\forall s > s^*$, $EU[s^*, \zeta] > 0$ and $\forall s \leq s^*$, $EU[s^*, \zeta] < 0$. In line with the best -response function $\Psi^A(.)$, $\exists\ \sigma_A(\Theta_{A,t=1})$ such that:

$$\sigma_A(\Theta_{A,t=1}) = \left\{ \begin{array}{ll} W & if\ s \leq s^* \\ S & if\ s > s^* \end{array} \right\}$$

which corresponds exactly to the notion of switching equilibrium that we stated in the main text.

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For depositor in $\Gamma_{B,t=1}$, the expected utility is given by expression: $EU[s^*, \zeta\prime] = [2P-1]\int_{s^*}^{s^*+\varepsilon} \pi(\theta, \delta(s^*, \theta))d\theta$. When bank A survives, $\Omega = \{S_A\}$, and bank B has a high idiosyncratic fundamental, $\delta(s^*, \theta)$ is low. Thus, the probability of an individual depositor staying becomes high and $EU[s, \zeta\prime]$ has relatively more of the $\int_{s^*}^{s*+\varepsilon} \pi(\theta, \delta(s^*, \theta))d\theta\ (>0)$ component and relatively less of the $\int_{s^*-\varepsilon}^{s^*} \pi(\theta, \delta(s^*, \theta))d\theta(<0)$. Thus,$EU[s_B, \zeta\prime] > 0$ when the idiosyncratic fundamental of bank B is high and when $\Omega = \{S_A\}$ is observed.

When $\Omega = \{F_A\}$ and bank B has a low idiosyncratic fundamental, $\delta(s^*, \theta)$ is high. Here, $EU[s, \zeta\prime]$ has relatively less of the $\int_{s^*}^{s^*+\varepsilon} \pi(\theta, \delta(s^*, \theta))d\theta\ (>0)$ component and relatively more of the $\int_{s^*-\varepsilon}^{s^*} \pi(\theta, \delta(s^*, \theta))d\theta\ (<0)$. Thus, $EU[s, \zeta\prime] < 0$ for low realisations of the idiosyncratic fundamental and when $\Omega = \{F_A\}$ is observed. Thus, the perfect Bayesian equilibrium concept will lead depositors in $\Gamma_{B,t=1}$, to follow a strategy along the following lines:

$$\sigma(\Theta_{t=1}^B) = \left\{ \begin{array}{lll} W & if & (\ \Omega^A = \{F^A\}) \cap (\ s \leq s^*) \\ S & if & (\ \Omega^A = \{S^A\}) \cap\ (\ s > s^*) \\ S \text{ or } W & if & \left\{ \begin{array}{c} either\ \left((\ \Omega^A = \{S^A\}) \cap\ (\ s \leq s^*)\right) \\ or\ \left((\ \Omega^A = \{F^A\}) \cap (\ s > s^*)\right)\right) \end{array} \right\} \end{array} \right\}$$

which is exactly the trigger equilibrium we defined in the main text.

PROOF OF PROPOSITION 4.2(a)

Proposition 4.2(a): (**Existence of a Trigger Equilibrium**) *In each depositor's game, there exists a threshold* s^* *such that he withdraws if* $s \leq s^*$ *and stays if* $s > s^*$

Proof: *(The following proof is valid for depositors of either bank - thus, we remove any subscripts or superscripts)*

We know that if $s < u^G - \varepsilon$, this means that $\theta < u^G$. By the dominance assumption we have elaborated in the main text, this implies that the net payoff to staying is negative in this region. In a similar line of thought, if $s > u^{Bad} + z + \varepsilon$, then $\theta > u^{Bad} + z$. We are here in the upper dominance region. Here, the net payoff to staying is strictly positive. By remarks 1 and 2, we are not interested in dominance regions however. The logic behind conceptualising the lower and upper dominance regions means that for the tails of the signal spaces, the net payoff structure takes unambiguous negative and positive values. Thus, there is a point in the signal space lying in the $\left[u^G - \varepsilon,\ u^{Bad} + z + \varepsilon\right]$ interval at which the net payoff is equal to zero. Let this point be point s^*. We shall proceed to explain the existence of s^* in two steps: (i) we will show that, for a marginal depositor, the net payoff to staying is increasing and continuous in s^* assuming that all depositors follow the switching strategy and (ii) we will show that for any $s \leq s^*$, this net payoff is negative and for any $s > s^*$, it is positive.

Step 1:

Each depositor in $\Gamma_{i,t=1}$, $i = \{A, B\}$, faces a uniform posterior belief over θ_i, conditional on observing his private signal s. Thus, we can model that posterior belief formally as : $\theta_i \mid s \sim Uniform[s - \varepsilon,\ s + \varepsilon]$, $\varepsilon \leq s \leq 1 - \varepsilon$. Assuming that all other depositors in $\Gamma_{i,t=1}$ follow a switching strategy, the proportion of patient depositors withdrawing early can be modelled as follows:

$$\delta[\theta, s^*] = \left\{ \begin{array}{lr} 1 & \theta < s^* - \varepsilon \\ \frac{1}{2} + \frac{(s^* - \theta)}{2\varepsilon} & s^* - \varepsilon \leq\ \theta \leq s^* + \varepsilon \\ 0 & \theta > s^* + \varepsilon \end{array} \right\}$$

Building on table 2, the net payoff to staying as opposed to withdrawing for each depositor in $\Gamma_{i,t=1}$can be re-parameterised in terms of θ and s^*as follows:

$$\Pi(\theta, s^*) = \int_{s^*-\varepsilon}^{s^*+\varepsilon} \pi(\theta, \delta[\theta, s^*]) \; d\theta \quad (= 0)$$

Recall that in chapter 4, we segregated the performance of a given bank into a bankruptcy and a no-bankruptcy space. Using the terminologies employed, it can be shown that:

In the Bankruptcy Condition Space, $\delta[\theta, s^*] > r \implies \{[\, \frac{1}{2} + \frac{(s^*-\theta)}{2\varepsilon}] > r\} \implies \{\theta < s^* + \varepsilon(1-2r)\}$

In the No-Bankruptcy Condition Space, $\delta[\theta, s^*] \leq r \implies \{[\, \frac{1}{2} + \frac{(s^*-\theta)}{2\varepsilon}] \leq r\} \implies \{\theta \geq s^* + \varepsilon(1-2r)\}$

Thus, we may partition $\Pi(\theta, s^*) = \int_{s^*-\varepsilon}^{s^*+\varepsilon} \pi(\theta, \delta[\theta, s^*]) \; d\theta$ into the Bankruptcy Condition Space and the No-Bankruptcy Condition Space as follows:

$$\Pi(\theta, s^*) = \int_{s^*+\varepsilon(1-2r)}^{s^*+\varepsilon} \{U\left[\frac{\{(1-\lambda)-\frac{\delta(1-\lambda)}{r}\}R(.)}{(1-\lambda)(1-\delta)}\right] - U(1)\} \; d\theta + \int_{s^*-\varepsilon}^{s^*+\varepsilon(1-2r)} \{U(0) - U\left[\frac{\lambda+r(1-\lambda)}{\lambda+\delta(1-\lambda)}\right]\} \; d\theta$$

$$= \int_{s^*+\varepsilon(1-2r)}^{s^*+\varepsilon} U\left[\frac{\{(1-\lambda)-\frac{\delta(1-\lambda)}{r}\}R(.)}{(1-\lambda)(1-\delta)}\right] d\theta - \int_{s^*-\varepsilon}^{s^*+\varepsilon(1-2r)} U\left[\frac{\lambda+r(1-\lambda)}{\lambda+\delta(1-\lambda)}\right] d\theta + \{U(0)[2\varepsilon(1-r)] - U(1)[2\varepsilon r].$$

Now, let $U\left[\frac{\{(1-\lambda)-\frac{\delta(1-\lambda)}{r}\}R(.)}{(1-\lambda)(1-\delta)}\right]$ be denoted as $\eta(\theta, s^*)$, let $U\left[\frac{\lambda+r(1-\lambda)}{\lambda+\delta(1-\lambda)}\right]$ be denoted as $\lambda(\theta, s^*)$, let $\{U(0)[2\varepsilon(1-r)] - U(1)[2\varepsilon r]$ be a constant, χ. A much simpler expression for $\Pi(\theta, s^*)$ would be as follows:

$$\Pi(\theta, s^*) = \int_{s^*+\varepsilon(1-2r)}^{s^*+\varepsilon} \eta(\theta, s^*) \; d\theta + \int_{s^*-\varepsilon}^{s^*+\varepsilon(1-2r)} \lambda(\theta, s^*) \; d\theta \; + \chi$$

We are interested in establishing how $\Pi(\theta, s^*)$ varies with s^*. Take derivatives with respect to s^* throughout:

$$\frac{\partial}{\partial s^*}\Pi(\theta, s^*) = \frac{\partial}{\partial s^*}\int_{s^*+\varepsilon(1-2r)}^{s^*+\varepsilon} \eta(\theta, s^*) \; d\theta + \frac{\partial}{\partial s^*}\int_{s^*-\varepsilon}^{s^*+\varepsilon(1-2r)} \lambda(\theta, s^*) \; d\theta$$

We proceed with the integrals separately:

$$\frac{\partial}{\partial s^*}\int_{s^*+\varepsilon(1-2r)}^{s^*+\varepsilon} \eta(\theta, s^*) \; d\theta = [\eta(\theta, s^*)]_{s^*+\varepsilon(1-2r)}^{s^*+\varepsilon} + \int_{s^*+\varepsilon(1-2r)}^{s^*+\varepsilon} \frac{\partial}{\partial s^*}[\eta(\theta, s^*)] \; d\theta$$

$$\frac{\partial}{\partial s^*}\int_{s^*-\varepsilon}^{s^*+\varepsilon(1-2r)} \lambda(\theta, s^*) \; d\theta = [\lambda(\theta, s^*)]_{s^*-\varepsilon}^{s^*+\varepsilon(1-2r)} + \int_{s^*-\varepsilon}^{s^*+\varepsilon(1-2r)} \frac{\partial}{\partial s^*}[\lambda(\theta, s^*)] \; d\theta$$

The following properties hold for $\eta(\theta, s^*)$ and $\lambda(\theta, s^*)$: (1) $\frac{\partial \eta(\theta,s^*)}{\partial \delta} < 0$, (2) $\frac{\partial \lambda(\theta,s^*)}{\partial \delta} < 0$, (3) $\frac{\partial \delta(\theta,s^*)}{\partial s^*} > 0$, (4) $\frac{\partial \delta(\theta,s^*)}{\partial \theta} < 0$, (5) $\left|\frac{\partial \delta(\theta,s^*)}{\partial s^*}\right| = \left|\frac{\partial \delta(\theta,s^*)}{\partial \theta}\right|$.

By (1) and (3), $\frac{\partial \eta(\theta,s^*)}{\partial s^*} < 0$. By (1) and (4), $\frac{\partial \eta(\theta,s^*)}{\partial \theta} > 0$. This gives rise to the important property that: $\int_{s^*+\varepsilon(1-2r}^{s^*+\varepsilon} \frac{\partial}{\partial \theta}[\eta(\theta,s^*)]d\theta$,as represented by $[\eta(\theta,s^*)]_{s^*+\varepsilon(1-2r)}^{s^*+\varepsilon}$, exceeds $\int_{s^*+\varepsilon(1-2r)}^{s^*+\varepsilon} \frac{\partial}{\partial s^*}[\eta(\theta,s^*)]\ d\theta$. This implies that $\frac{\partial}{\partial s^*}\int_{s^*+\varepsilon(1-2r)}^{s^*+\varepsilon} \eta(\theta,s^*)\ d\theta > 0$.

Repeating the same exercise for $\eta(\theta,s^*)$, we can see that by (6) $\frac{\partial \lambda(\theta,s^*)}{\partial s^*} < 0$, (7) $\frac{\partial \lambda(\theta,s^*)}{\partial \theta} > 0$. Given (5),(6) and (7), it can be established that $\int_{s^*-\varepsilon}^{s^*+\varepsilon(1-2r)} \frac{\partial}{\partial s^*}[\lambda(\theta,s^*)]$ $d\theta = -\int_{s^*-\varepsilon}^{s^*+\varepsilon(1-2r)} \frac{\partial}{\partial \theta}[\lambda(\theta,s^*)]\ d\theta$. Thus, $\frac{\partial}{\partial s^*}\int_{s^*-\varepsilon}^{s^*+\varepsilon(1-2r)} \lambda(\theta,s^*)\ d\theta = 0$. Through the values of $\frac{\partial}{\partial s^*}\int_{s^*+\varepsilon(1-2r)}^{s^*+\varepsilon} \eta(\theta,s^*)\ d\theta$ and $\frac{\partial}{\partial s^*}\int_{s^*-\varepsilon}^{s^*+\varepsilon(1-2r)} \lambda(\theta,s^*)\ d\theta$, we can establish that $\frac{\partial}{\partial s^*}\Pi(\theta,s^*) > 0$. Thus, there exists a value of s^* that solves the model for any $\Pi(\theta,s^*) = 0$. We have thus proved that $\Pi(\theta,s^*)$ is continuous in s^* over the $[s^*-\varepsilon,\ s^*+\varepsilon]$ range.

Step 2:

Define the net payoff to staying for a marginal depositor $\Pi(\theta,s^*) = \int_{s^*-\varepsilon}^{s^*+\varepsilon} \pi(\theta,\delta[\theta,s^*])$ $d\theta = 0$ (assuming that all other depositors follow a switching strategy). Also, define $\Pi(\theta,s) = \int_{s-\varepsilon}^{s+\varepsilon} \pi(\theta,\delta[\theta,s])\ d\theta$ as the net payoff to staying for a depositor who receives a signal s. The assumption of continuity means that $\Pi(\theta,s^*)$ is continuous in s^* in the signal range that allows for strategic interraction between depositors. Consider signals that are smaller than s^* : For extremely low realisations of signals, we will be in the lower dominance region and the net payoff will be strictly negative. For some $s \leq s^*$, the net payoff defined by the integral over the range $[s-\varepsilon,\ s+\varepsilon]$, involves adding a negative element to the structure and taking away part of the positive element. Thus, $\Pi(\theta,s)$ $(\equiv \int_{s-\varepsilon}^{s+\varepsilon} \pi(\theta,\delta[\theta,s])\ d\theta)$ $< \Pi(\theta,s^*)$ $\left(\equiv \int_{s^*-\varepsilon}^{s^*+\varepsilon} \pi(\theta,\delta[\theta,s^*])\ d\theta = 0\right)$. Thus, by a contagious element, any $s \leq s^*$ is compatible with negative net payoff. Depositors withdraw unambiguously when they receive a signal which is less than s^*. A similar line of thought will show that when $s > s^*$, $\Pi(\theta,s)$ $(\equiv \int_{s-\varepsilon}^{s+\varepsilon} \pi(\theta,\delta[\theta,s])\ d\theta)$ $> \Pi(\theta,s^*)$

$\left(\equiv \int_{s^*-\varepsilon}^{s^*+\varepsilon} \pi(\theta, \delta[\theta, s^*])\ d\theta = 0\right)$. By a contagiou s element, any $s > s^*$ is compatible with positive net payoff. Depositors stay unambiguously when they receive a signal which is more than s^*.

PROOF OF PROPOSITION 4.3

Proposition 4.3: (**Existence and Features of** θ^*) *By Propositions 4.2(a) and 4.2(b), there exists a threshold* θ^* *in each bank, above which the bank succeeds and below which the bank fails. In addition, for either bank, the location of* θ^* *has the property that* $\theta^*(u^{Bad}) > \theta^*(u^G)$ *with* $u^{Bad} > u^G$

Proof: *The analysis is relevant for depositors of either bank (except where otherwise stated).* We proceed in two steps:

Step 1: Existence of θ^*

We start with a marginal depositor in $\Gamma_{i,t=1}$who observes $s = s^*$ and who believes that all other depositors in $\Gamma_{i,t=1}$ will follow a switching strategy around s^*. For any particular realisations of the state of the common macroeconomic fundamental, there exists a critical value of θ that ensures that, from the returns technology given in table 1,

$$\theta^{crit} = u + z\delta[\theta, s^*] \text{ where } \delta[\theta, s^*] = \left\{ \begin{array}{ll} 1 & s^* > \theta + \varepsilon \\ \frac{1}{2} + \frac{(s^*-\theta)}{2\varepsilon} & \theta - \varepsilon \leq s^* \leq \theta + \varepsilon \\ 0 & s^* < \theta - \varepsilon \end{array} \right\}$$

Using the expression for $\delta[\theta, s^*]$, θ^{crit} can be expressed as:

$$\theta^{crit} = \left\{ \begin{array}{ll} u + z & s^* > \theta + \varepsilon \\ u + \frac{z}{2\varepsilon}\{(s^* - \theta) + \varepsilon\} & \theta - \varepsilon \leq s^* \leq \theta + \varepsilon \\ u & s^* < \theta - \varepsilon \end{array} \right\}$$

Thus,

$$\theta^{crit}(u) = \left\{ \begin{array}{ll} u + z & s^* > u + z + \varepsilon \\ \frac{z(s^*+\varepsilon)+2\varepsilon u}{z+2\varepsilon} & u - \varepsilon \leq s^* \leq u + z + \varepsilon \\ u & s^* \leq u - \varepsilon \end{array} \right\}$$

Step 2: Features of θ^*

When we showed $\Pi(\theta, s^*)$ as being strictly increasing in s^*(as per proposition 2(a)), we kept the state of the common macroeconomic fundamental as constant. However, with the property depicted in figure 2(b) in the graphical appendix of chapter 2, it turns out that whenever the common fundamental moves from a good state to a bad one, $\Pi(\theta, s^*, u^{Bad})$ lies below $\Pi(\theta, s^*, u^G)$ for any s^*. Thus, with the single-crossing property established in proposition 2(a) and 2(b), it turns out that s^* derived from $\Pi(\theta, s^*, u^{Bad})$ lies to the right of the s^* derived from $\Pi(\theta, s^*, u^G)$. How does that affect the threshold value of the idiosyncratic fundamental ? We know thatconditional on the state of the common fundamental, the critical threshold will be given by:

$$\theta^{crit}(\ u^{Bad}) = \left\{ \begin{array}{lr} u^{Bad} + z & s^* > \ u^{Bad} + z + \ \varepsilon \\ \frac{z(s^*+\varepsilon)+2\varepsilon u^{Bad}}{z+2\varepsilon} & u^{Bad} - \varepsilon \leq \ s^* \leq u^{Bad} \ + z \ + \ \varepsilon \\ u^{Bad} & s^* \leq \ u^{Bad} \ - \ \varepsilon \end{array} \right\}$$

$$\theta^{crit}(\ u^{G}) = \left\{ \begin{array}{lr} u^{G} + z & s^* > \ u^{G} + z + \ \varepsilon \\ \frac{z(s^*+\varepsilon)+2\varepsilon u^{G}}{z+2\varepsilon} & u^{G} - \varepsilon \leq \ s^* \leq u^{G} \ + z \ + \ \varepsilon \\ u^{G} & s^* \leq \ u^{G} \ - \ \varepsilon \end{array} \right\}$$

Thus, with $u^{Bad} > u^G$, it follows that $\theta^* \left(u^{Bad}\right) > \theta^*(\ u^G)$.

PROOF OF PROPOSITION 4.4:

Proposition 4.4: *(**Learning Mechanism**) Upon observing the failure of bank A, the probability that the common macroeconomic fundamental was in its bad state is more likely than unconditionally. Thus, (1)* $\Pr ob(u = u^{Bad} \mid F_A) > \Pr ob(u = u^{Bad}) > \Pr ob(u = u^{Bad} \mid S_A)$ *Similarly, conditional on observing the success of bank A, the probability that the common macroeconomic fundamental was in its good state is more likely than unconditionally. Thus, (2)* $\Pr ob(u = u^G \mid S_A) > \Pr ob(u = u^G) > \Pr ob(u = u^G \mid F_A)$

Proof:

(1) With the all-important property that, if $u^{Bad} > u^G$, then $\theta_A^*(u^{Bad}) > \theta_A^*(u^G)$, it can be inferred that $\theta_A^*(u^{Bad}) > k.\theta_A^*(u^{Bad}) + (1-k).\theta_A^*(u^G)$, $0 \leq k < 1$. Thus, $\frac{\theta_A^*(u^{Bad})}{k.\theta_A^*(u^{Bad})+(1-k).\theta_A^*(u^G)} > 1 \Rightarrow \frac{k.\theta_A^*(u^{Bad})}{k.\theta_A^*(u^{Bad})+(1-k).\theta_A^*(u^G)} > k$. This implies that: $\Pr ob(u = u^{Bad} \mid F_A) = \frac{k.\theta_A^*(u^{Bad})}{k.\theta_A^*(u^{Bad})+(1-k).\theta_A^*(u^G)} > k$. Subsequently, $\Pr ob(u = u^{Bad} \mid F_A) > \Pr ob(u = u^{Bad})$ where $\Pr ob(u = u^{Bad}) = k$. Similarly, if $u^{Bad} > u^G$, then $1 - \theta_A^*(u^{Bad}) < 1 - \theta_A^*(u^G)$. Thus, it must be the case that $1 - \theta_A^*(u^{Bad}) < k.[1 - \theta_A^*(u^{Bad})] + (1-k).[1 - \theta_A^*(u^G)]$. Thus, $\frac{1-\theta_A^*(u^{Bad})}{k.[1-\theta_A^*(u^{Bad})]+(1-k).[1-\theta_A^*(u^G)]} < 1 \Longrightarrow \frac{k.[1-\theta_A^*(u^{Bad})]}{k.[1-\theta_A^*(u^{Bad})]+(1-k).[1-\theta_A^*(u^G)]} < k$. Subsequently, $\Pr ob(u = u^{Bad} \mid S_A) < \Pr ob(u = u^{Bad})$ where $\Pr ob(u = u^{Bad}) = k$. This establishes the general result that: $\Pr ob(u = u^{Bad} \mid F_A) > \Pr ob(u = u^{Bad}) > \Pr ob(u = u^{Bad} \mid S_A)$

(2) can be proved in a similar way. With $\theta_A^*(u^G) < \theta_A^*(u^{Bad})$ by proposition 3 $\Rightarrow (1-k)\theta_A^*(u^G) < (1-k)\theta_A^*(u^{Bad})$. We can express $\theta_A^*(u^G)$ as a linear function: $\theta_A^*(u^G) < k\theta_A^*(u^G) + (1-k)\theta_A^*(u^{Bad})$. This implies that $\frac{\theta_A^*(u^G)}{k\theta_A^*(u^G)+(1-k)\theta_A^*(u^B)} < 1$. Multiply both sides by $(1-k)$ yields: $\frac{(1-k)\theta_A^*(u^G)}{k\theta_A^*(u^G)+(1-k)\theta_A^*(u^{Bad})} < (1-k)$. But $\frac{(1-k)\theta_A^*(u^G)}{k\theta_A^*(u^G)+(1-k)\theta_A^*(u^{Bad})} = \Pr ob(u = u^G \mid F_A)$ and $(1-k) = \Pr ob(u = u^G)$. This therefore suggests that $\Pr ob(u = u^G \mid F_A) < \Pr ob(u = u^G)$. With $\theta_A^*(u^G) < \theta_A^*(u^{Bad}) \Rightarrow 1-\theta_A^*(u^G) > 1-\theta_A^*(u^{Bad}) \Rightarrow (1-k)[1-\theta_A^*(u^G)] > (1-k)[1-\theta_A^*(u^{Bad})]$. In turn, $[1-\theta_A^*(u^G)] > k\left[1-\theta_A^*(u^G)\right] + (1-k)[1-\theta_A^*(u^{Bad})]$, which implies that $\frac{[1-\theta_A^*(u^G)]}{k\left[1-\theta_A^*(u^G)\right]+(1-k)[1-\theta_A^*(u^{Bad})]} > 1$. Multiplying both sides by $(1-k)$ yields $\frac{(1-k)[1-\theta_A^*(u^G)]}{k\left[1-\theta_A^*(u^G)\right]+(1-k)[1-\theta_A^*(u^{Bad})]} > (1-k)$. As derived above, $\frac{(1-k)[1-\theta_A^*(u^G)]}{k\left[1-\theta_A^*(u^G)\right]+(1-k)[1-\theta_A^*(u^{Bad})]} = \Pr ob(u = u^G \mid S_A)$ and $(1-k) = \Pr ob(u = u^G)$. This suggests that $\Pr ob(u = u^G \mid S_A) > \Pr ob(u = u^G)$. We have therefore proved the general result for (2), that, $\Pr ob(u = u^G \mid S_A) > \Pr ob(u = u^G) > \Pr ob(u = u^G \mid F_A)$

PROOF OF PROPOSITION 4.5:

Proposition 4.5: *The posterior estimates of the state of the common macroeconomic fundamental by depositors of bank B retain all mathematical proper-*

ties of propositions 2(a), 2(b) and 3. Furthermore, observing the failure (success) of bank A pushes the trigger of bank B upwards (downwards), such that $\theta_B^{F_A}(u) > \theta_B^*(u)$ $\left(\theta_B^{S_A}(u) < \theta_B^*(u) \text{ respectively}\right)$. *Thus, bank B now fails (succeeds) for larger realisations of its own idiosyncratic fundamentals.*

Proof:

Recall that when we derived the properties of $\Pi(\theta, s^*)$ in propositions 4.2(a) and 4.2(b), we took the state of the common fundamental as given. The analysis was thus confined to some conditional payoff function, where the state of the common fundamental was fixed. For depositors in bank A, the unconditional payoff is a linear combination of the net payoff structure over the prior probabilities of the state of the common fundamental. Thus, $\Pi(\theta, s^*) = \kappa$ $\Pi(\theta, s^*, u^{Bad}) + (1-\kappa)\ \Pi(\theta, s^*, u^G)$. Logically, it follows that $\Pi(\theta, s^*)$ is increasing in s^* and all analysis that we previously studied, will go through. There is a unique s^* and a corresponding $\theta^*(u)$.

Depositors of bank B have the advantage that they can learn about the state of the common fundamental by observing the event in bank A, where the learning mechanism was explicated in proposition 4.4. Thus, upon observing bank A' s failure, they will infer that there is greater likelihood that the common macroeconomic fundamental was in its bad state. Their unconditional payoff will be a linear combination of their conditional net payoff structure over the posterior probabilities of the state of the common fundamental. Thus, $\Pi^{/}(\theta, s^*) = \Pr ob(u = u^{Bad} \mid F_A)\ \Pi(\theta, s^*, u^{Bad}) + \Pr ob(u = u^G \mid F_A)$ $\Pi(\theta, s^*, u^G)$. It follows that $\Pi^{/}(\theta, s^*)$ is increasing in s^* and that there is a unique s^* for depositors in bank B as well. With the above assumption of $\Pr ob(u = u^{Bad} \mid F_A) > \kappa$ and $\Pr ob(u = u^G \mid F_A) < 1 - \kappa$, it turns out that $\Pi^{/}(\theta, s^*)$ lies below $\Pi(\theta, s^*)$. Let $\theta_B^{F_A}(u)$ denote the new critical threshold of bank B that is derived from $\Pi^{/}(\theta, s^*)$. By the properties of Proposition 4.3, step 2, it follows that $\theta_B^{F_A}(u) > \theta_B^*(u)$.

Upon observing bank A' s success, depositors of bank B will infer that there is greater likelihood that the common macroeconomic fundamental was in its good state, as per proposition 4. Their unconditional payoff will be given as follows: $\Pi^{/}(\theta, s^{*}) = \Pr ob(u = u^{Bad} \mid S_A)\ \Pi(\theta, s^{*}, u^{Bad}) + \Pr ob(u = u^{G} \mid S_A)$ $\Pi(\theta, s^{*}, u^{G})$. It follows that $\Pi^{/}(\theta, s^{*})$ is increasing in s^{*} and that there is a unique s^{*} . With the above assumption of $\Pr ob(u = u^{Bad} \mid S_A) < \kappa$ and $\Pr ob(u = u^{G} \mid S_A) > 1 - \kappa$, it turns out that $\Pi^{/}(\theta, s^{*})$ lies above $\Pi(\theta, s^{*})$. Let $\theta_B^{S_A}(u)$ denote the new critical threshold of bank B that is derived from $\Pi^{/}(\theta, s^{*})$. By the properties of Proposition 4.3, step 2, it follows that $\theta_B^{S_A}(u) < \theta_B^{*}(u)$.

A.4 Appendix for Chapter 5

NOTE ON TRIGGER EQUILIBRIUM

(A) FOLLOWING FROM THE EXISTENCE OF A TRIGGER EQUILIBRIUM

$$\begin{aligned}
\Pr ob(F_A \quad &| \quad u = u^{B}) = \theta_A^{*}(u^{Bad}) \\
\Pr ob(F_A \quad &| \quad u = u^{G}) = \theta_A^{*}(u^{G}) \\
\Pr ob(S_A \quad &| \quad u = u^{B}) = 1 - \theta_A^{*}(u^{Bad}) \\
\Pr ob(S_A \quad &| \quad u = u^{G}) = 1 - \theta_A^{*}(u^{G})
\end{aligned}$$

(B) BAYESIAN UPDATING

1) $\Pr ob(u = u^{Bad} \mid F_A) = \frac{P(F_A|u=u^{Bad})P(u=u^{Bad})}{P(F_A|u=u^{Bad})P(u=u^{Bad})+P(F_A|u=u^{G})P(u=u^{G})}$
$= \frac{k.\theta_A^{*}(u^{Bad})}{k.\theta_A^{*}(u^{Bad})+(1-k)\theta_A^{*}(u^{G})}$

2) $\Pr ob(u = u^{Bad} \mid S_A) = \frac{P(S_A|u=u^{Bad})P(u=u^{Bad})}{P(S_A|u=u^{Bad})P(u=u^{Bad})+P(S_A|u=u^{G})P(u=u^{G})}$
$= \frac{k.(1-\theta_A^{*}(u^{Bad}))}{k.(1-\theta_A^{*}(u^{Bad}))+(1-k)(1-\theta_A^{*}(u^{G}))}$

3) $Prob(u = u^{G} \mid S_A) = 1 - \Pr ob(u = u^{Bad} \mid S_A) = \frac{(1-k)(1-\theta_A^{*}(u^{G}))}{(1-k)(1-\theta_A^{*}(u^{Bad}))\ +\ k(1-\theta_A^{*}(u^{G}))}$

4) $Prob(u = u^G \mid F_A) = 1 - \Pr ob(u = u^{Bad} \mid F_A) = \frac{(1-k)\theta_A^*(u^G)}{(1-k)\theta_A^*(u^{Bad})\ +\ k\theta_A^*(u^G)}$

(C) CONDITIONAL PROBABILITIES

5) $\Pr(F_B \mid \{u = u^{Bad}\} \cap F_A) = \theta_{B,\ u^{Bad}}^{F_A}$

6) $\Pr(F_B \mid \{u = u^G\} \cap F_A) = \theta_{B,\ u^G}^{F_A}$

7) $\Pr(F_B \mid \{u = u^{Bad}\} \cap S_A) = \theta_{B,\ u^{Bad}}^{S_A}$

8) $\Pr(F_B \mid \{u = u^G\} \cap S_A) = \theta_{B,\ u^G}^{S_A}$

Similarly,

9) $\Pr(S_B \mid \{u = u^{Bad}\} \cap S_A) = 1 - \theta_{B,\ u^{Bad}}^{S_A}$

10) $\Pr(S_B \mid \{u = u^G\} \cap S_A) = 1 - \theta_{B,\ u^G}^{S_A}$

11) $\Pr(S_B \mid \{u = u^{Bad}\} \cap F_A) = 1 - \theta_{B,\ u^{Bad}}^{F_A}$

12) $\Pr(S_B \mid \{u = u^G\} \cap F_A) = 1 - \theta_{B,\ u^G}^{F_A}$

(D) CONDITIONAL PROBABILITIES (CONTD..)

13) $Pr(F_B \mid \Theta_{t=1}^B, F_A) = \Pr(F_B \mid \{u = u^{Bad}\} \cap F_A) \Pr(\{u = u^{Bad}\} \mid F_A) +$ $\Pr(F_B \mid \{u = u^G\} \cap F_A) \Pr(\{u = u^G\} \mid F_A)$.

$$=\theta_{B,\ u^{Bad}}^{F_A} \left[\frac{k.\theta_A^*(u^{Bad})}{k.\theta_A^*(u^{Bad})+(1-k)\theta_A^*(u^G)}\right] + \theta_{B,\ u^G}^{F_A} \left[1 - \left(\frac{k.\theta_A^*(u^{Bad})}{k.\theta_A^*(u^{Bad})+(1-k)\theta_A^*(u^G)}\right)\right]$$

$$=\left(\theta_{B,\ u^{Bad}}^{F_A} - \theta_{B,\ u^G}^{F_A}\right) \left[\frac{k.\theta_A^*(u^{Bad})}{k.\theta_A^*(u^{Bad})+(1-k)\theta_A^*(u^G)}\right] + \theta_{B,\ u^G}^{F_A}$$

14) $Pr(F_B \mid \Theta^B_{t=1}, S_A) = \Pr(F_B \mid \{u = u^{Bad}\} \cap S_A) \Pr(\{u = u^{Bad}\} \mid S_A) +$ $\Pr(F_B \mid \{u = u^G\} \cap S_A) \Pr(\{u = u^G\} \mid S_A)$.

$$=\theta^{S_A}_{B,\ u^{Bad}} \left[\frac{k.(1-\theta^*_A(u^{Bad}))}{k.(1-\theta^*_A(u^{Bad}))+(1-k)(1-\theta^*_A(u^G))}\right]+\theta^{S_A}_{B,\ u^G}\left[1-\left(\frac{k.(1-\theta^*_A(u^{Bad}))}{k.(1-\theta^*_A(u^{Bad}))+(1-k)(1-\theta^*_A(u^G))}\right)\right]$$
$$=\left(\theta^{S_A}_{B,\ u^{Bad}}-\theta^{S_A}_{B,\ u^G}\right)\left[\frac{k.(1-\theta^*_A(u^{Bad}))}{k.(1-\theta^*_A(u^{Bad}))+(1-k)(1-\theta^*_A(u^G))}\right]+\theta^{S_A}_{B,\ u^G}$$

Proof. $Pr(F_B \mid \Theta^B_{t=1}, F_A) > Pr(F_B \mid \Theta^B_{t=1}, S_A)$

Clearly, (i) $\frac{k.\theta^*_A(u^{Bad})}{k.\theta^*_A(u^{Bad})+(1-k)\theta^*_A(u^G)} > \frac{k.(1-\theta^*_A(u^{Bad}))}{k.(1-\theta^*_A(u^{Bad}))+(1-k)(1-\theta^*_A(u^G))}$ as established in main text

(ii) $\theta^{F_A}_{B,\ u^{Bad}} - \theta^{F_A}_{B,\ u^G} > \theta^{S_A}_{B,\ u^{Bad}} - \theta^{S_A}_{B,\ u^G}$

(iii) $\theta^{F_A}_{B,\ u^G} > \theta^{S_A}_{B,\ u^G}$

Thus, each of the component part of $Pr(F_B \mid \Theta^B_{t=1}, F_A)$ exceeds that of $Pr(F_B \mid \Theta^B_{t=1}, S_A)$.This completes this mini-proof. ■

Similarly,

15) $Pr(S_B \mid \Theta^B_{t=1}, S_A) = \Pr(S_B \mid \{u = u^{Bad}\} \cap S_A) \Pr(\{u = u^{Bad}\} \mid S_A) +$ $\Pr(S_B \mid \{u = u^G\} \cap S_A) \Pr(\{u = u^G\} \mid S_A)$.

$$=1-\left\{\frac{k(1-\theta^*_A(u^{Bad}))\theta^*_B(u^{Bad})+(1-k)(1-\theta^*_A(u^G))\theta^*_B(u^G)}{1-k\theta^*_A(u^{Bad})-(1-k)\theta^*_A(u^G)}\right\}$$

16) $Pr(S_B \mid \Theta^B_{t=1}, F_A) = \Pr(S_B \mid \{u = u^{Bad}\} \cap F_A) \Pr(\{u = u^{Bad}\} \mid F_A) +$ $\Pr(S_B \mid \{u = u^G\} \cap F_A) \Pr(\{u = u^G\} \mid F_A)$.

$$=1-\left\{\frac{k\theta^*_A(u^{Bad})\theta^*_B(u^{Bad}) + (1-k)\theta^*_A(u^G)\theta^*_B(u^G)}{k\theta^*_A(u^{Bad}) + (1-k)\theta^*_A(u^G)}\right\}$$

Proof. Similarly, it can be proved that $Pr(S_B \mid \Theta^B_{t=1}, S_A) > Pr(S_B \mid \Theta^B_{t=1}, F_A)$

The proof is left to the reader. ■

17) Event probabilities - A summary

(i) $Pr(F_B \mid \Theta^B_{t=1}, F_A) = \left\{\frac{k\theta^*_A(u^{Bad})\theta^*_B(u^{Bad}) + (1-k)\theta^*_A(u^G)\theta^*_B(u^G)}{k\theta^*_A(u^{Bad}) + (1-k)\theta^*_A(u^G)}\right\}$

(ii) $Pr(F_B \mid \Theta^B_{t=1}, S_A) = \left\{\frac{k(1-\theta^*_A(u^{Bad}))\theta^*_B(u^{Bad})+(1-k)(1-\theta^*_A(u^G))\theta^*_B(u^G)}{1-k\theta^*_A(u^{Bad})-(1-k)\theta^*_A(u^G)}\right\}$

(iii) $Pr(S_B \mid \Theta^B_{t=1}, F_A) = 1-\left\{\frac{k\theta^*_A(u^{Bad})\theta^*_B(u^{Bad}) + (1-k)\theta^*_A(u^G)\theta^*_B(u^G)}{k\theta^*_A(u^{Bad}) + (1-k)\theta^*_A(u^G)}\right\}$

(iv) $Pr(S_B \mid \Theta^B_{t=1}, S_A) = 1-\left\{\frac{k(1-\theta^*_A(u^{Bad}))\theta^*_B(u^{Bad})+(1-k)(1-\theta^*_A(u^G))\theta^*_B(u^G)}{1-k\theta^*_A(u^{Bad})-(1-k)\theta^*_A(u^G)}\right\}$

(E) UNCONDITIONAL PROBABILITIES

18) $P(F_A) = \Pr(F_A \mid u = u^{Bad})\Pr(u = u^{Bad}) + \Pr(F_A \mid u = u^G)\Pr(u = u^G)$.

19) $P(S_A) = \Pr(S_A \mid u = u^{Bad})\Pr(u = u^{Bad}) + \Pr(S_A \mid u = u^G)\Pr(u = u^G)$.

20) $P(F_B) = Pr(F_B \mid \Theta^B_{t=1}, F_A)P(F_A) + Pr(F_B \mid \Theta^B_{t=1}, S_A)P(S_A)$

21) $P(S_B) = Pr(S_B \mid \Theta^B_{t=1}, F_A)P(F_A) + Pr(S_B \mid \Theta^B_{t=1}, S_A)P(S_A)$

A.5 Notes for Chapter 5

I. The negative signal associated with SOC comes from the fact that depositors of the second bank may interpret the information in the following way: if something is wrong in the first bank and depositors wishing to withdraw are not getting back their dues due to policy suspension, depositors of the second bank may also not get back their dues in the future if their bank meets the same fate tomorrow. After all, the two banks are positively linked to the common macroeconomic fundamental - they are likely to share the same fate at a later stage. Thus, the best response of those depositors of the second bank is to withdraw now. By suspending convertibility in one bank to try to limit contagion, preventive measures taken at one bank has led to a run on the second bank !

J. The signal could be described as thus: if depositors of the second bank observe the first bank receiving financial aid in the form of LOLR, they may interpret the information in the following two ways:

(i) They may interpret this as a sign that something is wrong about the first bank. Since the two banks are perceived to be connected to the macro fundamental, they may reckon that their bank (the second bank) may meet the same fate in the future. So, they decide to withdraw now (Negative Signal)

(ii) They may alternatively interpret this LOLR intervention at the first bank as a sign that confidence is being maintained in the first bank through LOLR and its temporary illiquidity problem is being solved. Therefore, no spillover effect will be felt in their bank (the second bank) (Positive Signal).

Notice that, in the case of the negative signal, the LOLR being given to the first bank has actually created a channel of contagion of its own to the second bank.

A.6 Appendix for Chapter 7

PROOF OF CLAIM 7.1:

Claim 7.1: *Given a continuous objective function and the existence of resource and incentive constraints that are compact and non-empty, there exists a solution to the optimal program. The assumptions of concavity and twice differentiability of the objective function, ensure that the solution is positive.*

The Optimal Program satisfies the following Euler equation: $U'(c_1) = E(R)\,U'(c_2)$ *and a resulting non-contingent term structure of demand deposit repayment, represented as follows:*

$c_1 = \frac{\kappa}{\lambda},\ \ c_2 = \frac{(1-\kappa)E(R)}{(1-\lambda)},\quad c_1 < c_2.$

Thus, $e = 1$ *in the foreign exchange market.*

Proof. We reproduce the optimization problem from the main text as follows:

$$\underset{c_1}{max}\ \lambda U(c_1) + (1-\lambda)\,U(c_2)$$

s.t

$$\lambda c_1 \leq \kappa$$

$$c_2 = \frac{(1-\kappa)\,E\,(R) + \kappa - \lambda c_1}{1-\lambda}$$

$$c_1 \leq c_2$$

As in Allen and Gale (1998), (2004), we proceed in deriving the Euler equation, using a two-stepped approach:

Step 1:

Here, we maximise the objective function subject to the budget constraints in periods $t = 1$ and $t = 2$, without the incentive compatibility constraints and we show that, as part of the first-order condition, the incentive compatibility constraint will be satisfied. We set up the *Lagrangian function* without the incentive-compatibility constraint and discuss the *Kuhn-Tucker conditions*:

The *Lagrangian Function* is as follows:

$L = \{\lambda U\,(c_1) + (1-\lambda)\,U\,(c_2)\} + \chi_1\,[\kappa - \lambda c_1] + \chi_2\,[(1-\kappa)\,E\,(R) + \kappa - \lambda c_1 - (1-\lambda)\,c_2]$

where χ_1 and χ_2 are the lagrangian multipliers.

Kuhn-Tucker Conditions:

1.

(a) $\frac{\partial L}{\partial c_1} = \lambda U'\,(c_1) - \lambda \chi_1 - \lambda \chi_2 \geq 0$

$\Leftrightarrow\; U'\,(c_1) \geq \chi_1 + \chi_2$

(b) $c_1 \geq 0$

(c) $c_1\,[U'\,(c_1) - \chi_1 - \chi_2] = 0$ (complementary-slackness condition)

2.

(a) $\frac{\partial L}{\partial c_2} = (1-\lambda)\,U'\,(c_2) - (1-\lambda)\,\chi_2 = 0$

$\Leftrightarrow U'\,(c_2) = \chi_2$

3.

(a) $\frac{\partial L}{\partial \chi_1} = \kappa - \lambda c_1 \geq 0$

(b) $\chi_1 \geq 0$

(c) $\chi_1\,(\kappa - \lambda c_1) = 0$ (complementary-slackness condition)

4.

(a) $\frac{\partial L}{\partial \chi_2} = (1-\kappa)\,E\,(R) + \kappa - \lambda c_1 - (1-\lambda)\,c_2 \geq 0$

(b) $\chi_2 \geq 0$

(c) $\chi_2 \left[(1-\kappa) E(R) + \kappa - \lambda c_1 - (1-\lambda) c_2\right] = 0$ (complementary-slackness condition)

We know that since $c_2 = \frac{(1-\kappa)E(R)+\kappa-\lambda c_1}{1-\lambda}$, $\left[(1-\kappa) E(R) + \kappa - \lambda c_1 - (1-\lambda) c_2\right] = 0$. Thus, $\chi_2 > 0$.

From conditions 1(c) and 2(a), it follows that: $U'(c_1) - \chi_1 - U'(c_2) = 0$.

If $\chi_1 = 0$, $\kappa > \lambda c_1$ i.e the budget constraint in period $t = 1$ is non-binding. Thus, $U'(c_1) = U'(c_2) \Leftrightarrow c_1 = c_2$.

If $\chi_1 > 0$, $\kappa = \lambda c_1$ i.e the budget constraint in period $t = 1$ is binding. Thus, $U'(c_1) - U'(c_2) > \chi_1 \Leftrightarrow U'(c_1) > U'(c_2)$. This implies that $c_1 < c_2$.

This completes proof of step 1.

Step 2:

Since $c_2 = \frac{(1-\kappa)E(R)+\kappa-\lambda c_1}{1-\lambda}$, replace in objective function as follows:

$$\underset{c_1}{max} \left\{ \lambda U(c_1) + (1-\lambda) U\left(\frac{(1-\kappa) E(R) + \kappa - \lambda c_1}{1-\lambda}\right)\right\}$$

First-Order Condition (FOC) with respect to κ:

$(1-\lambda) U'\left(\frac{(1-\kappa)E(R)+\kappa-\lambda c_1}{1-\lambda}\right) . \left(\frac{1-E(R)}{1-\lambda}\right) \lesseqgtr 0$

Thus, κ (i.e the value of the short technology) is non-zero. The planner holds just the minimum amount needed to satisfy period $t = 1$ consumption i.e $\kappa = \lambda c_1$.

The new optimization problem becomes:

$$\underset{c_1}{max} \left\{ \lambda U(c_1) + (1-\lambda) U\left(\frac{(1-\lambda c_1) E(R)}{1-\lambda}\right)\right\}$$

First-Order Condition (FOC) with respect to κ:

$\lambda U'(c_1) + (1-\lambda) U'(c_2) . \left\{\frac{-\lambda}{1-\lambda} \ E(R)\right\} = 0$

Thus, the Euler equation simplifies to the following : $U'(c_1) = U'(c_2) E(R)$ with $c_1 = \frac{\kappa}{\lambda}$ and $c_2 = \frac{(1-\kappa)E(R)}{1-\lambda}$

Q.E.D ■

PROOF OF LEMMAS 7.1 AND 7.2

Lemma 7.1: *Given parametric restrictions* $\lambda < \frac{2\kappa}{\kappa+1}$ *and* $\gamma R < 1$*, it follows that* $\frac{1}{2} < R^{*} < 1$

Proof. Given the optimal term structure of demand deposit payments (c_1^*, c_2^*), the bank's optimal portfolio plan in period $t = 0$, $(\kappa^*, 1-\kappa^*)$, is chosen to maximise depositors' expected utility subject to zero-(expected) profit constraint. Condition $\lambda < \frac{2\kappa}{\kappa+1}$ simply asserts that, whilst the proportion of early withdrawals is λ, we assume in the paper that λ is chosen such that it is less than $\frac{2\kappa}{\kappa+1}$, with the optimal values of κ substituted therein.

First part of proof: Given $\lambda < \frac{2\kappa}{\kappa+1}$, it follows that $R^{*} > \frac{1}{2}$

Following on from the above inequality, it is obvious that varying the values of κ will keep λ between 0 and 1.

For example, as $\kappa \to \infty$, the numerator and the denominator of quotient $\frac{2\kappa}{\kappa+1}$, will converge to ∞. Thus, applying L'Hopital's Rule, it follows that: $\underset{\kappa\to\infty}{Lim}\frac{f(\kappa)}{g(\kappa)} = \underset{\kappa\to\infty}{Lim}\frac{f'(\kappa)}{g'(\kappa)}$ where $f(\kappa) = 2\kappa$ and $g(\kappa) = \kappa + 1$. Thus, by L'Hopital's Rule, $\underset{\kappa\to\infty}{Lim}\frac{2\kappa}{\kappa+1} = \underset{\kappa\to\infty}{Lim}\frac{2}{1} = 2$.

We know that κ is bounded i.e $0 < \kappa \leq 1$. Thus, as $\kappa \to 1$, the numerator and the denominator of quotient $\frac{2\kappa}{\kappa+1}$, will converge to the same constant, such that, $\frac{2\kappa}{\kappa+1} \longrightarrow 1$. Similarly, as $\kappa \to 0$, the numerator and the denominator of quotient $\frac{2\kappa}{\kappa+1}$, will converge to a different constant, such that, $\frac{2\kappa}{\kappa+1} \longrightarrow 0$. Thus, varying the values of κ between 0 and 1 will keep λ between 0 and 1. Our assumption that λ lies below $\frac{2\kappa}{\kappa+1}$, with the optimal values of κ substituted therein, thus holds.

Manipulating conditions $\lambda < \frac{2\kappa}{\kappa+1} \Longrightarrow \frac{\kappa}{\kappa+1} > \frac{\lambda}{2}$. Thus, $\frac{\kappa}{\lambda} > \frac{1}{2}(\kappa+1)$. From the bank's optimisation program, we know that $c_1 = \frac{\kappa}{\lambda}$. Thus, $c_1 > \frac{1}{2}(\kappa+1)$. This condition simplifies to $c_1 - \frac{1}{2} > \frac{1}{2}\kappa$ and eventually to: $c_1 - \kappa > \frac{1}{2}(1-\kappa)$. Thus, $\frac{c_1-\kappa}{1-\kappa} > \frac{1}{2}$. We know that for optimal portfolio values and optimal term structure of payments, $R^{*} = \frac{c_1^*-\kappa^*}{1-\kappa^*}$. Thus, $\frac{c_1^*-\kappa^*}{1-\kappa^*} > \frac{1}{2}$ is tantamount to writing that $R^{*} > \frac{1}{2}$.

Second part of proof: Given $\gamma R < 1$, it follows that $R^{*} < 1$

We hypothesised earlier if $\gamma R > 1$, the bank's optimal portfolio strategy will consist of investing all endowments in the long asset and to liquidate the long asset prematurely in order to satisfy the liquidity needs of impatient depositors. Such a strategy would yield a higher return than one which involves keeping reserve requirements and satisfying impatient depositors' needs out of the safe asset. Under the hypothesis $\gamma R > 1$, the liquidated long asset yields more in period $t = 1$ than the short asset.

Conversely, in order to guarantee that the bank will hold a positive amount of the safe and of the risky asset (i.e $0 < \kappa < 1$), $\gamma R < 1$. The upper bound of R (i.e $\frac{\kappa(1-\lambda)}{\gamma\lambda(1-\kappa)} \equiv R^{\max}$). If $R = R^{\max}$, it follows that $\gamma R^{\max} < 1$. We know that $\gamma R^{\max} = \frac{\kappa(1-\lambda)}{\lambda(1-\kappa)} \equiv R^{*}$. Since $\gamma R^{\max} < 1$, it follows that $R^{*} < 1$.

Thus, restrictions $\lambda < \frac{2\kappa}{\kappa+1}$ and $\lambda R < 1$ ensure that overall, $\frac{1}{2} < R^{*} < 1$. See illustration in the main text for the relationship between γR , R^{*} and

boundedness of R^{*}

Q.E.D ■

Lemma 7.2: *Given that* $\frac{\kappa}{1-\kappa} > \frac{\lambda}{1-\lambda}(\gamma R)$, *it follows that:* $0 < \gamma R < R$

Proof. Given that $\frac{\kappa}{1-\kappa} > \frac{\lambda}{1-\lambda}(\gamma R)$, we know that the upper bound of R is $\frac{\kappa(1-\lambda)}{\gamma\lambda(1-\kappa)}\ (\equiv R^{\max})$. Thus, $0 < R < \frac{\kappa(1-\lambda)}{\gamma\lambda(1-\kappa)}$. Multiply throughout by γ will yield: $0 < \gamma R < \frac{\kappa(1-\lambda)}{\lambda(1-\kappa)}\ (\equiv R^{*})$.

See illustration in (Graphical) Appendix for the relationship between γR , R^{*} and $R^{\max}$

Q.E.D ■

PROOF OF PROPOSITION 7.1

Proposition 7.1: *Bank runs occur if and only if* $R \leq R^{*}$ *but, in the absence of any interventionist policies, will fail to contagiously spread to the foreign exchange sector and generate a currency crisis as per definition 7.3. A necessary and sufficient condition that guarantees this result is assumption* $\frac{\kappa}{1-\kappa} > \frac{\lambda}{1-\lambda}(\gamma R)$

Proof. With $\frac{\kappa}{1-\kappa} > \frac{\lambda}{1-\lambda}(\gamma R)$ **,** we can re-arrange and simplify to get: $\kappa(1-\lambda) > \gamma(1-\kappa)\lambda R$.

This boils down to: $\kappa > \lambda\kappa + \gamma(1-\kappa)\lambda R$. Dividing everywhere by λ yields: $\frac{\kappa}{\lambda} > \kappa + \gamma(1-\kappa)R$.

We know that $c_1^* = \frac{\kappa}{\lambda}$. Thus, substituting c_1^* in condition $\frac{\kappa}{\lambda} > \kappa + \gamma(1-\kappa)R$ yields: $c_1^* > \kappa + \gamma(1-\kappa)R$.

We can simplify and arrive at: $1 > \frac{\kappa+\gamma(1-\kappa)R.}{c_1^*}$. We know that $\frac{\kappa+\gamma(1-\kappa)R.}{c_1^*} = \Xi$ (i.e the fraction of depositors withdrawing early and guaranteed to receive c_1^* under the sequential service constraint (SSC)). Assumption $\frac{\kappa}{1-\kappa} > \frac{\lambda}{1-\lambda}(\gamma R)$ enables us to go beyond and prove a yet more powerful result: We know that each unit of dollar is converted into pesos at rate $1:1$, assuming that the soft peg is maintained. Each unit of dollar has been converted into pesos and invested into κ of the safe asset and $1-\kappa$ of the long asset. We also know that $\gamma R^* < R^*$ where $R^* < 1$. It thus turns out that $\kappa + (1-\kappa)\gamma R < 1$. Thus, each dollar in the central bank reserves is more than enough to compensate proportion Ξ of depositors who are promised c_1^* under the sequential service constraint. The total amount of dollars to be provided is Ξc_1^* (i.e $\kappa + (1-\kappa)\gamma R$). At an exchange rate of $1:1$, this equal to $\kappa + (1-\kappa)\gamma R$ dollars. But we have seen that if assumption $\frac{\kappa}{1-\kappa} > \frac{\lambda}{1-\lambda}(\gamma R)$ holds, this is less than 1 (i.e amount that the central bank has in its coffers). Thus, no currency crisis as per definition 3 occurs.

Q.E.D ■

PROOF OF COROLLARY 7.4

Corollary 7.4: *A devaluation-induced bank run leads to lower welfare than a purely-information-based bank run*

Proof. Assume that the discount rate is zero and that all other banks in the economy can be modelled as a "representative bank". The proof is in two steps: Step 1: We need to show that the banking contract allocation is Pareto inferior to the second-best allocation and Step 2: we build on the analysis by showing that welfare under an information-induced banking crisis is higher than under a devaluation-induced banking crisis.

Step 1: Banking Contract is Pareto-Inferior to Central Bank's Second-Best Program

$W^{Banking} = \int_{e^*}^{\infty} \Psi\ U(c_1(e))\ f(e)\ de + \int_0^{e^*} [\lambda U(c_1(e)) + (1-\lambda) U(c_2(e))]$ $f(e)\ de$

where $e^* = \frac{\lambda(1-\kappa)R}{\kappa(1-\lambda)}$, $\Psi = \frac{\kappa+\gamma(1-\kappa)\frac{R}{e}}{c^*}$ and , as mentioned in the main text, $\int_{e^*}^{\infty} \Psi\ U(c_1(e))\ f(e)\ de$ is the element of the banking contract that makes the bank vulnerable to the risks of a currency devaluation and $\int_0^{e^*} [\lambda U(c_1(e)) + (1-\lambda) U(c_2(e))]\ f(e)\ de$ is the element of the banking contract that induces truthtelling behaviour.

A close observation to the second-best allocation of the Central Bank as planner, leads us to re-write welfare in the second-best program as follows:

$W^{Second} = \int_0^{e^*} E[\lambda U(c_1(e)) + (1-\lambda) U(c_2(e))]\ f(e)\ de + \int_{e^*}^{\infty} E[\lambda U(c_1(e)) + (1-\lambda) U(c_2(e))]\ f(e)\ de$

By comparing welfare under banking allocation and under the second-best program, we arrive at the following: $W^{Second} - W^{Banking} = \int_0^{e^*} E[\lambda U(c_1(e)) + (1-\lambda) U(c_2(e))]\ f(e)\ de + \int_{e^*}^{\infty} E[\lambda U(c_1(e)) + (1-\lambda) U(c_2(e))]\ f(e)\ de - \int_{e^*}^{\infty} \Psi\ U(c_1(e))\ f(e)\ de - \int_0^{e^*} [\lambda U(c_1(e)) + (1-\lambda) U(c_2(e))]\ f(e)\ de$

This boils down to the much simpler representation:

$W^{Second} - W^{Banking} = \int_{e^*}^{\infty} E[\lambda U(c_1(e)) + (1-\lambda) U(c_2(e))]\ f(e)\ de - \int_{e^*}^{\infty} \Psi\ U(c_1(e))\ f(e)\ de$. When we focus on the $(e^*, \infty]$ region, we remove the expectations operator and we get:

$W^{Second} - W^{Banking} = \int_{e^*}^{\infty} [(\lambda - \Psi) U(c_1(e)) + (1-\lambda) U(c_2(e))]\ f(e)\ de > 0$

Now that we have proved that a banking contract, where depositors receive interim news about the shadow exchange rate, is Pareto inferior to the second-best, we are well placed to compare the welfare implications of an information-induced run v/s a devaluation-induced run.

Step 2: Information-Induced Banking Crisis vs Devaluation-Induced Banking Crisis

Under a devaluation-induced banking crisis, the welfare of depositors, who under the Sequential-Service Constraint (SSC) rule, receive full contractual payments of c_1^* is given by: $W_{devaluation-induced} = \int_{e^*}^{\infty} \left(\frac{\kappa+\gamma(1-\kappa)\frac{R}{e}}{c_1^*}\right) U\left(c_1\left(e\right)\right)$ $f\left(e\right)\, de$. By contrast, under a information-induced banking crisis, the welfare of depositors, who under the Sequential-Service Constraint (SSC) rule, receive full contractual payments of c_1^* is given by: $W_{\inf o-induced} = \int_{e^*}^{\infty}$ $\left(\frac{\kappa+\gamma(1-\kappa)R}{c_1^*}\right) U\left(c_1\left(R\right)\right)\, f\left(R\right)\, dR$. Since in both cases, those who are promised contractual payment get the same amount c_1^* , comparison of welfare will boil down to comparing the proportion of those depositors who receive full contractual payments for average values of e and of R.

Consider the proportion of individuals who receive full payment c_1^* in the case of a *devaluation-induced banking crisis*: $\frac{\kappa+\gamma(1-\kappa)\frac{R}{e}}{c_1^*}$. Recall that, in this case, R is non-stochastic and e is what depositors receive interim news about. As $e \to e^*$, $\frac{\kappa+\gamma(1-\kappa)\frac{R}{e}}{c_1^*} \to \frac{\kappa+\gamma(1-\kappa)\frac{R}{e^*}}{c_1^*}$; as $e \to \infty$, $\frac{\kappa+\gamma(1-\kappa)\frac{R}{e}}{c_1^*} \to \frac{\kappa}{c_1^*}$. Thus, as e rises from e^* to ∞, the proportion of depositors who receive full contractual payments under the sequential service constraint changes at a rate of $\frac{\gamma(1-\kappa)\frac{R}{e}}{c_1^*}$ from $\frac{\kappa+\gamma(1-\kappa)\frac{R}{e^*}}{c_1^*}$ to $\frac{\kappa}{c_1^*}$ (where $\frac{\kappa+\gamma(1-\kappa)\frac{R}{e^*}}{c_1^*} > \frac{\kappa}{c_1^*}$) . Let the graph (depicting the proportion of those withdrawing early and who receive full contractual payments) be denoted $G(e)$. It shows how this proportion varies with $e \in (e^*, \infty]$.

Consider the proportion of individuals who receive full payment c_1^* in the case of a *information-induced banking crisis:* $\frac{\kappa+\gamma(1-\kappa)R}{c_1^*}$. Recall that, in this case, R is stochastic and is basically what depositors receive interim news about. As $R \to R^*$, $\frac{\kappa+\gamma(1-\kappa)R}{c_1^*} \to \frac{\kappa+\gamma(1-\kappa)R^*}{c_1^*}$; as $R \to 0$, $\frac{\kappa+\gamma(1-\kappa)R}{c_1^*} \to \frac{\kappa}{c_1^*}$. Thus, as R rises from 0 to R^*, the proportion of depositors who receive full contractual payments under the sequential service constraint changes at a rate of $\frac{\gamma(1-\kappa)R}{c_1^*}$ from $\frac{\kappa}{c_1^*}$ to $\frac{\kappa+\gamma(1-\kappa)R^*}{c_1^*}$ (where $\frac{\kappa+\gamma(1-\kappa)R^*}{c_1^*} > \frac{\kappa}{c_1^*}$) . This is shown in illustration (v) in Appendix E. Let the graph (depicting the proportion of those withdrawing early and who receive full contractual payments) be denoted $H(R)$. It shows how this proportion varies with $R \in (0, R^*]$.

Using the theory of approximation, we can argue that since e knows no upper bound, any arbitrary average value of e between e^* and ∞, lies closer to ∞ than to e^*. Thus, the value of $G(e)$ at an average value of e, lies closer to $\frac{\kappa}{c_1^*}$ than to $\frac{\kappa+\gamma(1-\kappa)\frac{R}{e^*}}{c_1^*}$. Let's hypothesise that this value is approximately $\frac{\kappa}{c_1^*}$. With the same language mode, we can argue that since R has an upper bound, the average value of R lying between 0 and R^* is $\frac{R^*}{2}$. Thus, the value of $H(R)$, evaluated at $\frac{R^*}{2}$ is: $\frac{\kappa+\gamma(1-\kappa)\frac{R^*}{2}}{c_1^*}$.

Since $\frac{\kappa+\gamma(1-\kappa)\frac{R^*}{2}}{c_1^*} > approx\ \frac{\kappa}{c_1^*}$, the average proportion of depositors receiving full contractual payments under the sequential service constraint is higher for an information-induced bank run than for a devaluation-induced bank run[3]. The contractual payments to those who will end up receiving c_1^* being the same, it turns out that (aggregate) welfare for those who receive c_1^* is lower in a devaluation-induced bank run. This completes the proof.

Q.E.D ■

A.7 Notes for Chapter 7

Allen and Gale (2001) consider an open-economy equivalent of their 1998 paper and show that a planner, by trading state-contingent contracts in the world market (characterised by risk-neutral agents), can replicate the first-best allocation, with depositors bearing no risks. They then consider how optimal risk sharing can be reached with an open-economy version of the banking system, in which the bank is allowed to trade bonds internationally i.e borrow in home currency and invest the proceedings in the foreign currency. This is achieved mainly by monetary policy, which, by changing the price level, introduces some form of state-contingent variations in the relative values of bonds held. However, borrowing in the home currency is a feature of rich industrial states. For an EME, borrowing is mainly in terms of the foreign currency. As such, to shift risks to the international market, bankruptcy (i.e positive liquidation of the risky

[3] This argument can be viewed from a different angle - the proportion of depositors who do not receive anything under the sequential service constraint, is higher for a devaluation-induced bank run than for an information-induced bank run.

asset) must be allowed. Thus, in an EME, Allen and Gale (2001) conjecture that the optimal risk-sharing arrangement does not eliminate all risks to depositors.

A.8 Notes for Chapter 8

Our ideology is similar to Allen and Gale (2001) in that we use Allen and Gale (1998) as starting point . We use an equilibrium selection device to get rid of equilibrium indeterminacy by using the concept of precise signals as potential belief coordinator device. In the first variant, the signal is about the bank's stochastic fundamentals However, Allen and Gale (2000a) focus essentially on risk-sharing contracts between two countries and on how, for a risk-averse country that has contracted debt in the home currency, exchange rate fluctuations may introduce state-contingent variations in the relative values of bonds and allow the country to export risk to the foreign (risk-neutral) country. By so-doing, the banking system replicates the allocation of some fictitious planner who is allowed to trade state-contingent contracts. Furthermore, Allen and Gale (2001) explain the occurrence of the 'twin' crises (banking and currency crises) as a joint probability event that occurs when bank fundamentals go wrong. They do not address causality issues between a banking crisis and a currency crisis. Our approach to financial fragility differs from Allen and Gale (1998), (2001) in that we do not focus on the notion of risk transfers across countries but rather, on how, by offering risk-sharing agreements to depositors, causality issues between a banking crisis and a currency crisis may occur. We explicate clear conditions under which a banking crisis may, by itself, lead to a currency crisis and analyse the necessary parametric restrictions for this causality to arise. Addressing the cause-effect relationship theoretically gives us a comparative advantage in assessing welfare implications of safeguard policies and of the appropriatedness of different exchange rate regimes that may best suit an EME.

A.9 A Theoretical Model of Twin Crisis

In this section, we provide an illustration of our model findings, through a carefully worked example. The model that we shall use is drawn from Jacklin et al. (1988)[4]. Let the utility function be a square-root function: $U(c_{tj}) = \sqrt{c_{tj}}$, $j, t = \{1, 2\}$. c_{tj} simply stands for consumption of individual of type j in period t. Basically, in Jacklin et al (1988), there are two individuals ($j = \{1, 2\}$) and each individual derives utility from consuming in both periods, ($t = \{1, 2\}$). The utility of individual 1 is thus: $\sqrt{c_{11}} + \rho_1 A \sqrt{c_{12}}$ where ρ_1 is the discount factor for individual 1 and A is some constant; the utility of individual 2 is given by expression: $\sqrt{c_{12}} + \rho_2 A \sqrt{c_{22}}$. Assume that $\rho_2 = 1$ and that $\rho_1 = \rho < 1$. We assume that the aggregate distribution of type 1 and type 2 individuals is $(\lambda, 1 - \lambda)$.

There are two technologies: a safe storage technology and a risky investment technology. The risky technology is as described in example 1 of chapter 6. It yields a stochastic return of R where R has a bernoulli distribution: R_L with probability θ and R_H with probability $1-\theta$, where $0 < \theta < 1$ and $0 < R_L < R_H$. The ex-ante exchange rate is assumed to be 1.

We assume that in period $t = 0$, investors do not know their type. In the same period, the bank will decide on the optimal investment strategy - it decides to devote κ of resources to the safe storage asset and $1 - \kappa$ to the risky asset. Depositors receive interim information about R and about $t = 2$ (expected) exchange rate at the beginning of period $t = 1$. The specification of the model, other to what is described here, is similar to a typical bank run model. The bank's optimization problem is as follows:

[4] Actually, the model derived in this section is that of Jacklin et al (1988), applied to the open economy. See Moheeput (2003) for more details.

$$\max \quad \lambda \left[\sqrt{c_{11}} + \rho A \sqrt{c_{11}}\right] + (1-\lambda)\left[\sqrt{c_{12}} + A\sqrt{c_{22}}\right]$$

s.t

$$\lambda c_{11} + (1-\lambda)\, c_{12} \leq \kappa$$

$$\lambda c_{21} + (1-\lambda)\, c_{22} \leq R_H\,(1-\kappa)$$

$$\lambda c_{21}\left(\frac{R_L}{R_H}\right) + (1-\lambda)\, c_{22}\left(\frac{R_L}{R_H}\right) \leq R_L\,(1-\kappa)$$

$$\sqrt{c_{11}} + \rho A\sqrt{c_{21}} \geq \sqrt{c_{12}} + \rho A\sqrt{c_{22}}$$

$$\sqrt{c_{12}} + A\sqrt{c_{22}} \geq \sqrt{c_{11}} + A\sqrt{c_{21}}$$

$$A = 1 - \theta + \theta\sqrt{\frac{R_L}{R_H}}$$

where $\lambda c_{11} + (1-\lambda)\, c_{12} \leq \kappa$ denotes the resources constraint in period $t = 1$; $\lambda c_{21} + (1-\lambda)\, c_{22} \leq R_H\,(1-\kappa)$ denotes the resource constraint in period $t = 2$, assuming the good state of the world; $\lambda c_{21}\left(\frac{R_L}{R_H}\right) + (1-\lambda)\, c_{22}\left(\frac{R_L}{R_H}\right) \leq R_L\,(1-\kappa)$ denotes the resource constraint in period $t = 2$, assuming the bad state of the world; $\sqrt{c_{11}} + \rho A\sqrt{c_{21}} \geq \sqrt{c_{12}} + \rho A\sqrt{c_{22}}$ denotes the incentive-compatibility constraint for individuals of type 1; $\sqrt{c_{12}}+A\sqrt{c_{22}} \geq \sqrt{c_{11}}+A\sqrt{c_{21}}$ is the incentive-compatibility constraint for individuals of type 2. The solution to the above optimization problem is, as demonstrated in Jacklin et al (1988):

$c_{11} = \frac{1}{\lambda(1+\rho^2 A^2 R_H)+(1-\lambda)\left(\delta_1^2+A^2 R_H \delta_2^2\right)}$

$c_{12} = \delta_1^2 c_{11}$

$c_{21} = \left(A\rho R_H\right)^2 c_{11}$

$c_{22} = \left(A\delta_2 R_H\right)^2 c_{11}$

where:

$\delta_1 = \frac{1+\rho A^2 R_H(\rho-\lambda(1-\rho))}{1+\rho A^2 R_H(1-\lambda(1-\rho))}$ and $\delta_2 = \frac{1+\rho A^2 R_H^2(1-\lambda(1-\rho))}{1+\rho A^2 R_H(1-\lambda(1-\rho))}$

$\delta_1 < 1$

Remark: $c_{11} > c_{12}-$ *The payment made, in period* $t = 1$, *to type 1 depositor is higher than that made to type 2 depositor*

Thus, some type 2 depositors may prefer to type 1 withdrawal stream to their own withdrawal stream. If this happens, then an information-induced bank run occurs.

Sufficient Conditions for a Bank Run

In period $t = 1$, some type 2 depositors receive interim information that leads them to update their beliefs about R or to expect a currency devaluation $(e_2 > 1)$ or both. It will be assumed that, in the case in which the belief updating mechanics is about R, depositors update their probability assessment of $R = R_L$ from θ to $\hat{\theta}$ (the new posterior belief about R). When this happens, the bank will be unable to meet the demand for all type 1 withdrawals in period $t = 1$, thus triggering a bank run.

The bank run conditions, in this example, will be as follows:

$\sqrt{c_{12}} + A_1\sqrt{c_{22}} < \sqrt{c_{11}} + A_1\sqrt{c_{21}}$ where $A_1 = 1 - \hat{\theta} + \hat{\theta}\sqrt{\frac{R_L}{R_H}}$

$\sqrt{c_{12}} + A_2\sqrt{c_{22}} < \sqrt{c_{11}} + A_2\sqrt{c_{21}}$ where $A_2 = 1 - \theta\sqrt{\frac{1}{e_2}} + \theta\sqrt{\frac{R_L}{R_H e_2}}$

$\sqrt{c_{12}} + A_3\sqrt{c_{22}} < \sqrt{c_{11}} + A_3\sqrt{c_{21}}$ where $A_3 = (1 - \hat{\theta})\sqrt{\frac{1}{e_2}} + \hat{\theta}\sqrt{\frac{R_L}{R_H e_2}}$

The above conditions for a bank run imply that:

$A_i < \frac{\sqrt{c_{11}}-\sqrt{c_{12}}}{\sqrt{c_{22}}-\sqrt{c_{21}}}$ where $i = 1, 2, 3$.

Using the above expression as well as the solution of the optimization program, the following condition is obtained:

$\frac{\sqrt{c_{11}}-\sqrt{c_{12}}}{\sqrt{c_{22}}-\sqrt{c_{21}}} = \frac{1-\delta_1}{AR_H(\delta_2-\rho)}$

By replacing the right hand side of the above expression by the relevant expressions for δ_1 and δ_2 (as derived above), we obtain:

$\frac{\sqrt{c_{11}}-\sqrt{c_{12}}}{\sqrt{c_{22}}-\sqrt{c_{21}}} = \rho A$

Thus, condition $A_i < \frac{\sqrt{c_{11}}-\sqrt{c_{12}}}{\sqrt{c_{22}}-\sqrt{c_{21}}}$ transforms itself into the more tractable: $A_i < A$, $i = 1, 2, 3$

Mechanics of a Banking and Currency Crisis

CASE 1: Banking Crisis leads to a Currency Crisis

Hypothesis 1: *Some type 2 depositors receive interim bad information about R but no information about the exchange rate expected to prevail in period $t = 2$*

The sufficient condition for a bank run is: $\hat{\theta} > \rho\theta + (1-\rho)\left(\frac{\sqrt{R_H}}{\sqrt{R_H}-\sqrt{R_L}}\right)$. Let $\bar{\theta}$ denote $\rho\theta + (1-\rho)\left(\frac{\sqrt{R_H}}{\sqrt{R_H}-\sqrt{R_L}}\right)$. Thus, informed type 2 depositors prefer type 1 withdrawal stream to type 2 withdrawal stream if their updated assessment of $\hat{\theta}$ gets above $\bar{\theta}$. This last condition guarantees the existence of a bank run. If the Central Bank is forced to use its reserves to bailout the commercial bank, this triggers a collapse of the currency, *irrespective of whether there is interim bad news about the expected exchange rate or not.*

CASE 2: Currency Crisis leads to a Banking Crisis

Hypothesis 2: *Some informed type 2 depositors receive interim bad information about the exchange rate expected to prevail in period $t = 2$, but no interim bad information about the bank's performance, R.*

The sufficient condition for a bank run is: $(1-\theta)\sqrt{\frac{1}{e_2}}+\theta\sqrt{\frac{R_L}{R_H}} < \rho\left(1-\theta+\theta\sqrt{\frac{R_L}{R_H}}\right)$. Simplifying and rearranging, we get: $e_2 > \frac{1}{\rho^2}$. Thus, if an economy engages in "liability dollarisation" and offers liability contracts denominated in the foreign currency, an interim bad news about the expected exchange rate (condition $e_2 > \frac{1}{\rho^2}$) will trigger a bank run through balance sheet effects, *irrespective of the performance of the bank's portfolio.*

CASE 3: Co-existence of a Currency Crisis and a Banking Crisis

Hypothesis 3: *Some informed type 2 depositors receive interim bad information about R (leading them to expect a re-adjustment of posterior beliefs) and about the exchange rate expected to prevail in period $t = 2$ (leading them to expect a currency devaluation)*

The sufficient condition for financial fragility is: $\left(1-\hat{\theta}\right)\sqrt{\frac{1}{e_2}}+\hat{\theta}\sqrt{\frac{R_L}{R_H}} < \rho\left(1-\theta+\theta\sqrt{\frac{R_L}{R_H}}\right)$. Simplifying and re-arranging yields: $\hat{\theta} > \frac{\sqrt{\frac{1}{e_2}}-\rho\left(1-\theta+\theta\sqrt{\frac{R_L}{R_H}}\right)}{\sqrt{\frac{1}{e_2}}\left(1-\sqrt{\frac{R_L}{R_H}}\right)}$.
Note that $\frac{\sqrt{\frac{1}{e_2}}-\rho\left(1-\theta+\theta\sqrt{\frac{R_L}{R_H}}\right)}{\sqrt{\frac{1}{e_2}}\left(1-\sqrt{\frac{R_L}{R_H}}\right)} < \rho\theta+(1-\rho)\left(\frac{\sqrt{R_H}}{\sqrt{R_H}-\sqrt{R_L}}\right)$.

This suggests that when there is an unexpected currency devaluation, interim bad news about R will more likely trigger a bank run, relative to the case in which there is no such expectation.

Claim: *The purpose of this section was to specify the robustness of the results developed in this paper, by using as illustration, a general open economy model of Jacklin et al (1988). In EMEs with short-term debt contracts denominated in foreign currency, devaluation may lead to "non linear" deterioration in the balance sheet of commercial banks, with increased burden of indebtedness and lower net worth. Thus, for EMEs that receive substantial capital inflows and that are characterised by liability dollarisation, a banking crisis and a currency crisis are more likely to be interlinked. If the banking system is poorly managed and suffers from lax regulation and supervision standards, then a banking and a* *currency crisis are more likely to occur if the country's overall macroeconomic management programme is also poor. The last illustration highlights this fact.*

THE END